Climate Change on the Kenai Peninsula

Ed Berg, PhD, Ecologist

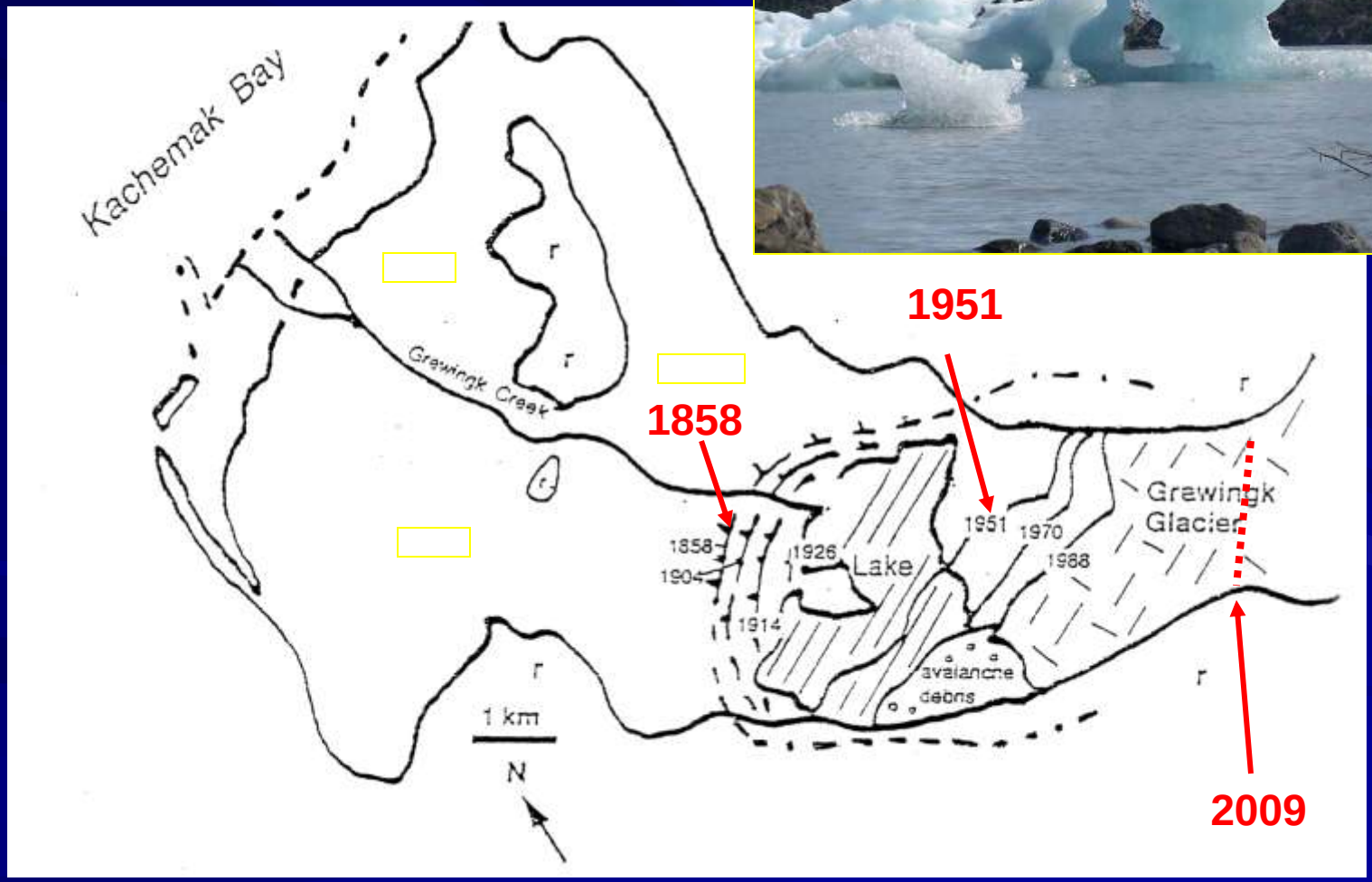
US Fish & Wildlife Service
Kenai National Wildlife Refuge

Kachemak Bay Climate Change Conference
February 2010

Kenai Climate Change Effects

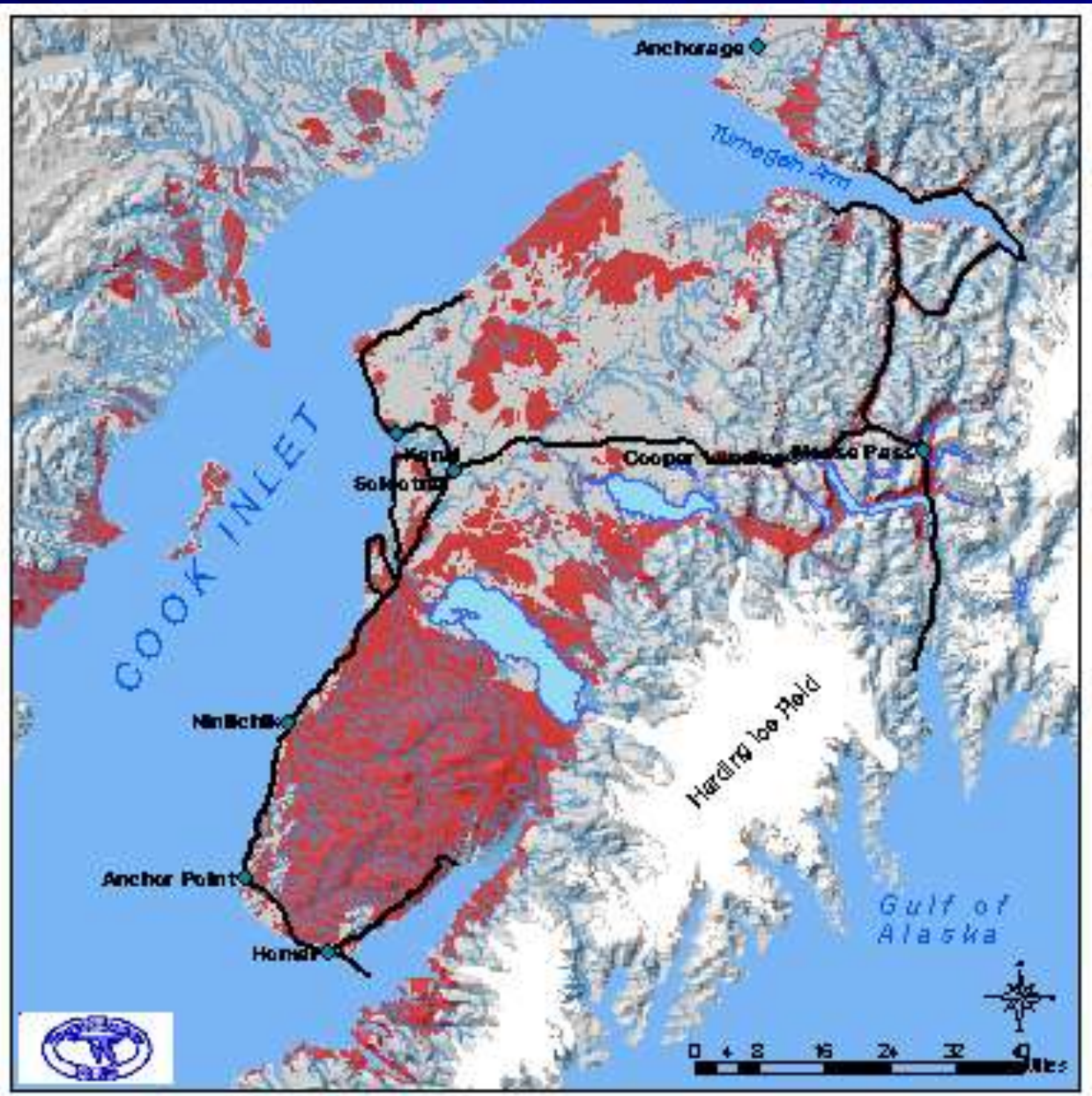
- Retreating Glaciers
- Spruce Bark Beetle Outbreaks
- Drying Wetlands
- Declining Available Water
- Changing Fire Regime
- A Warm and Very Dry Past
- Ice-Shoved Ramparts
- Sea-Level Rise vs. Uplift

Grewingk Glacier Retreat Post–Little Ice Age (Since 1850s)



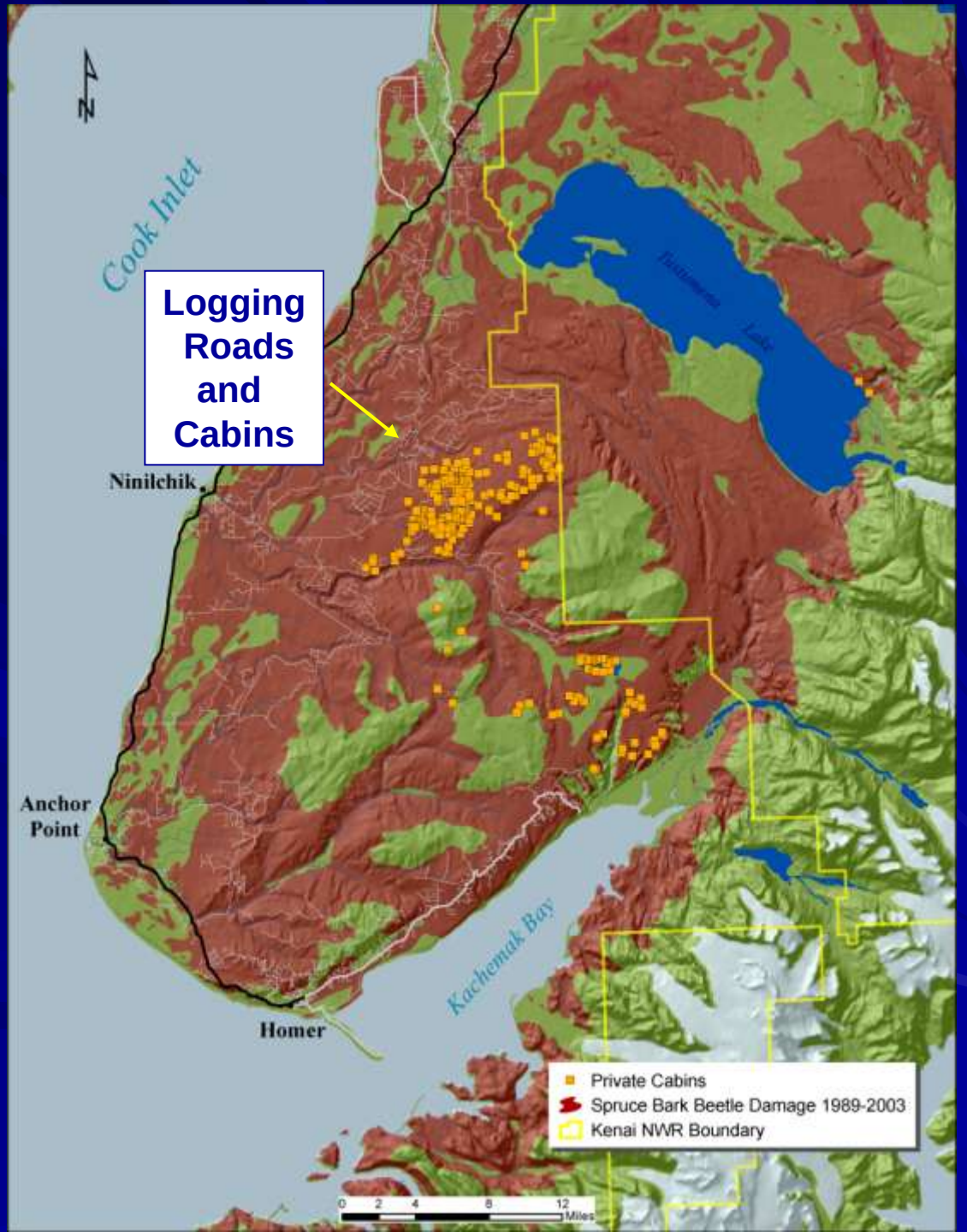
Kenai Cumulative Outbreak

Total Beetle Kill
3.0 million acres
in Southcentral Alaska
and
1.1 million acres
on the Kenai



Spruce
Bark Beetle
1989-2002

Subdivision and Cabin Fever Follow Logging of Beetle-killed Forest



A New Savannah in the Logged Areas

Growth Releases in Tree-rings

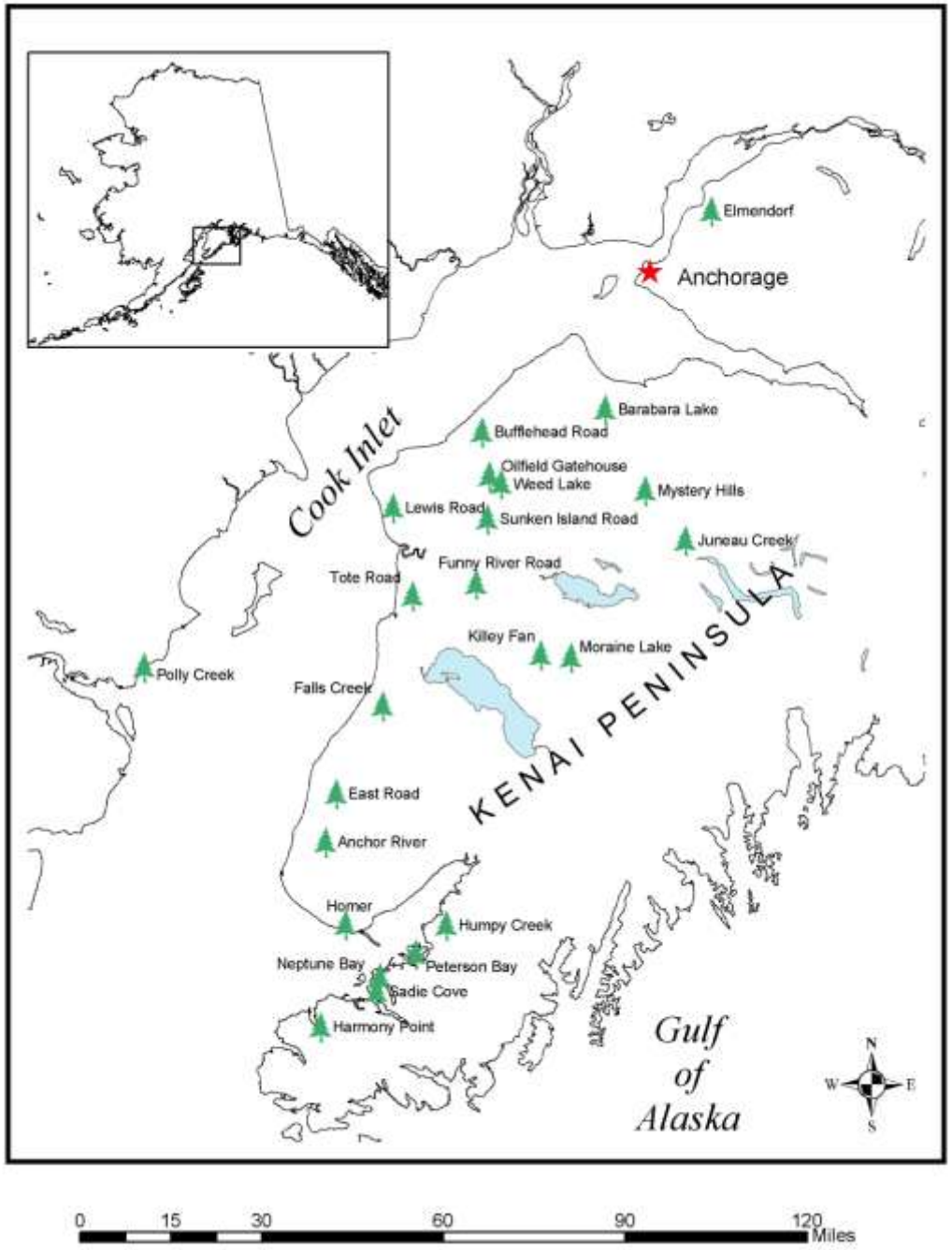
- **Bark Beetles Kill the Larger Trees First.**

- **Smaller Trees are Released from Competition, and Grow Faster.**

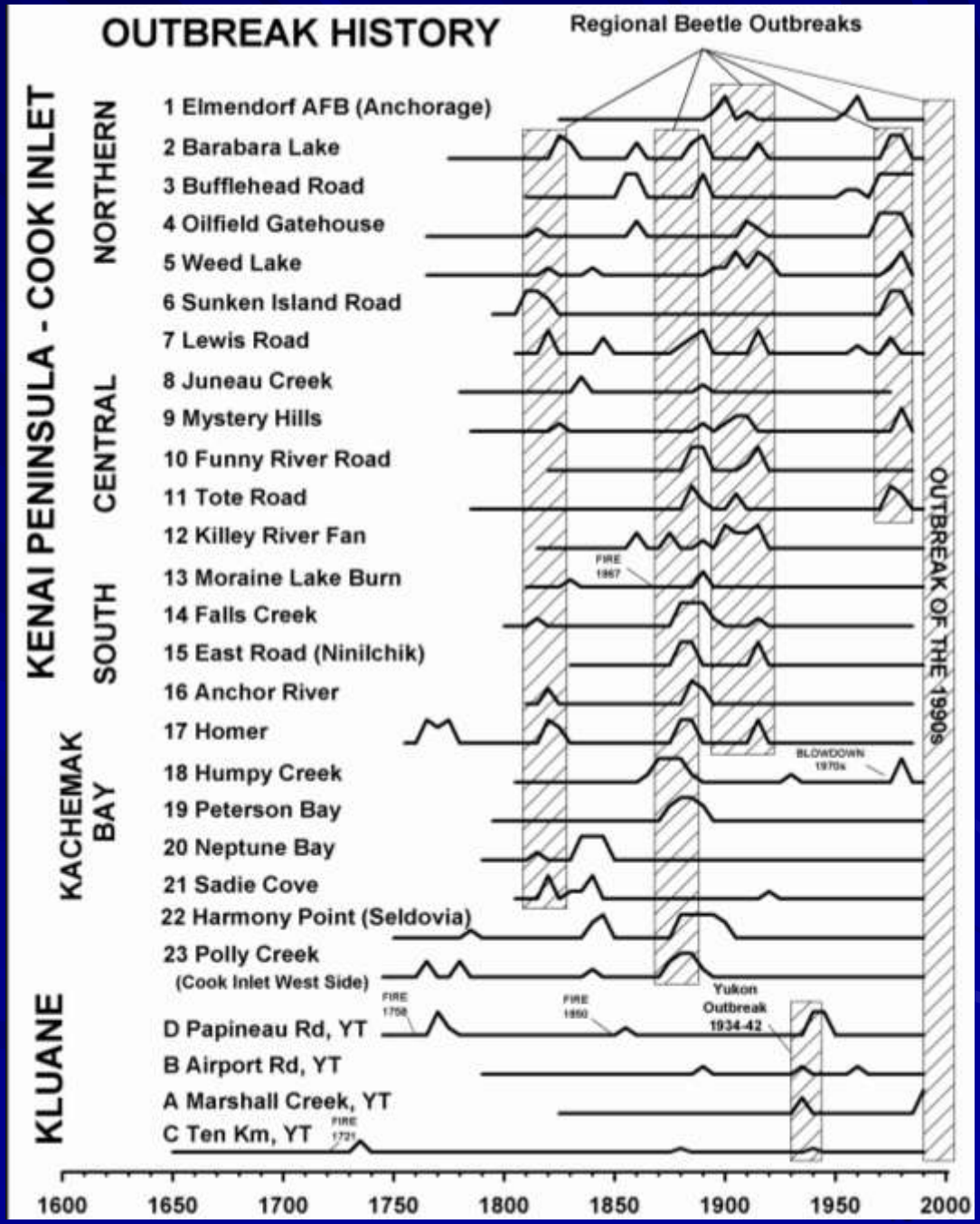
An Extreme Example of a Growth Release

1884 Release

Kenai Peninsula Outbreak History Study Sites



Spruce Bark Beetle Outbreak Summary



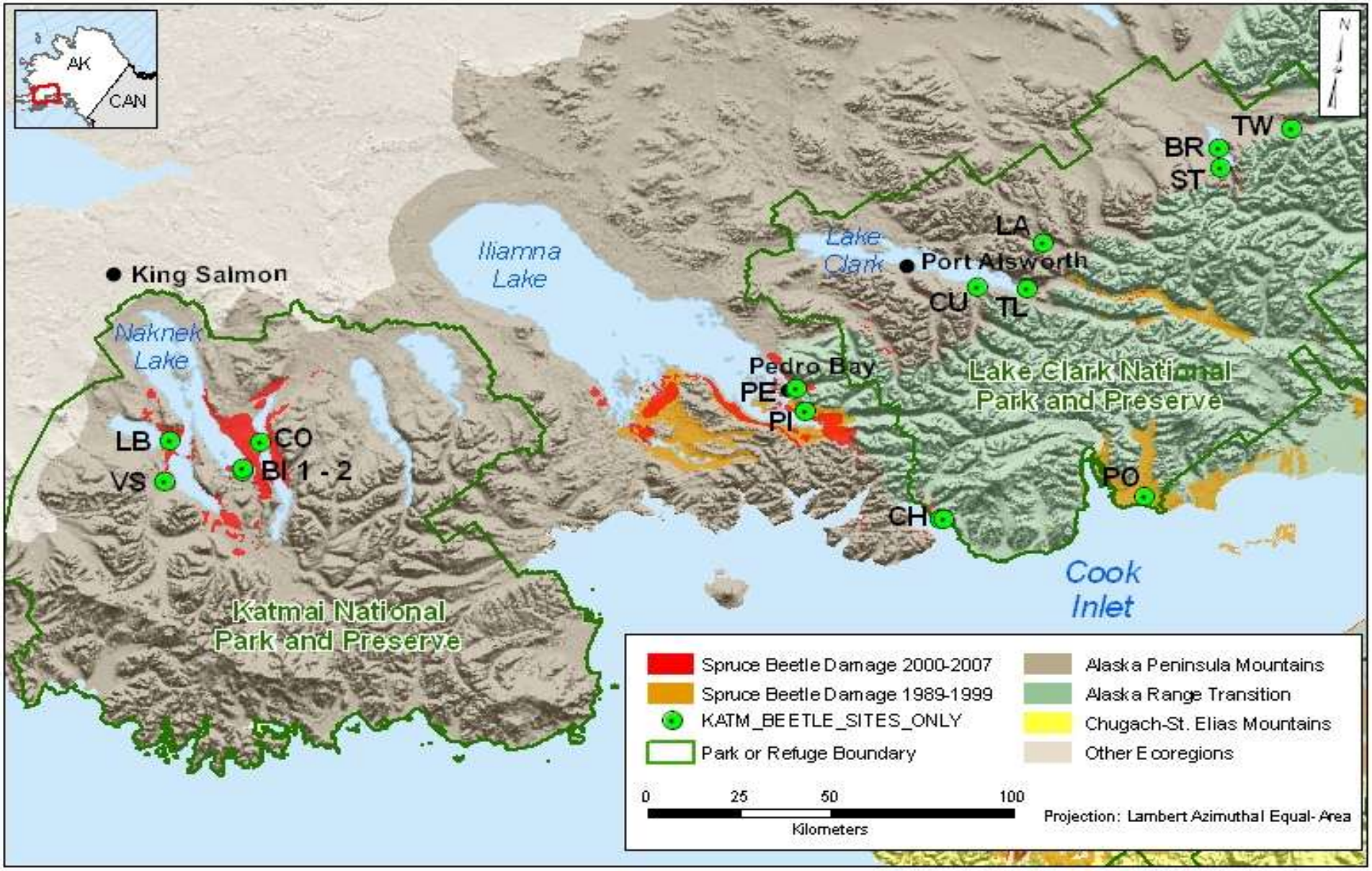
Lake Clark and Katmai Spruce Bark Beetle Outbreak History

Working with:

Rosemary Sherriff –
Humboldt State University

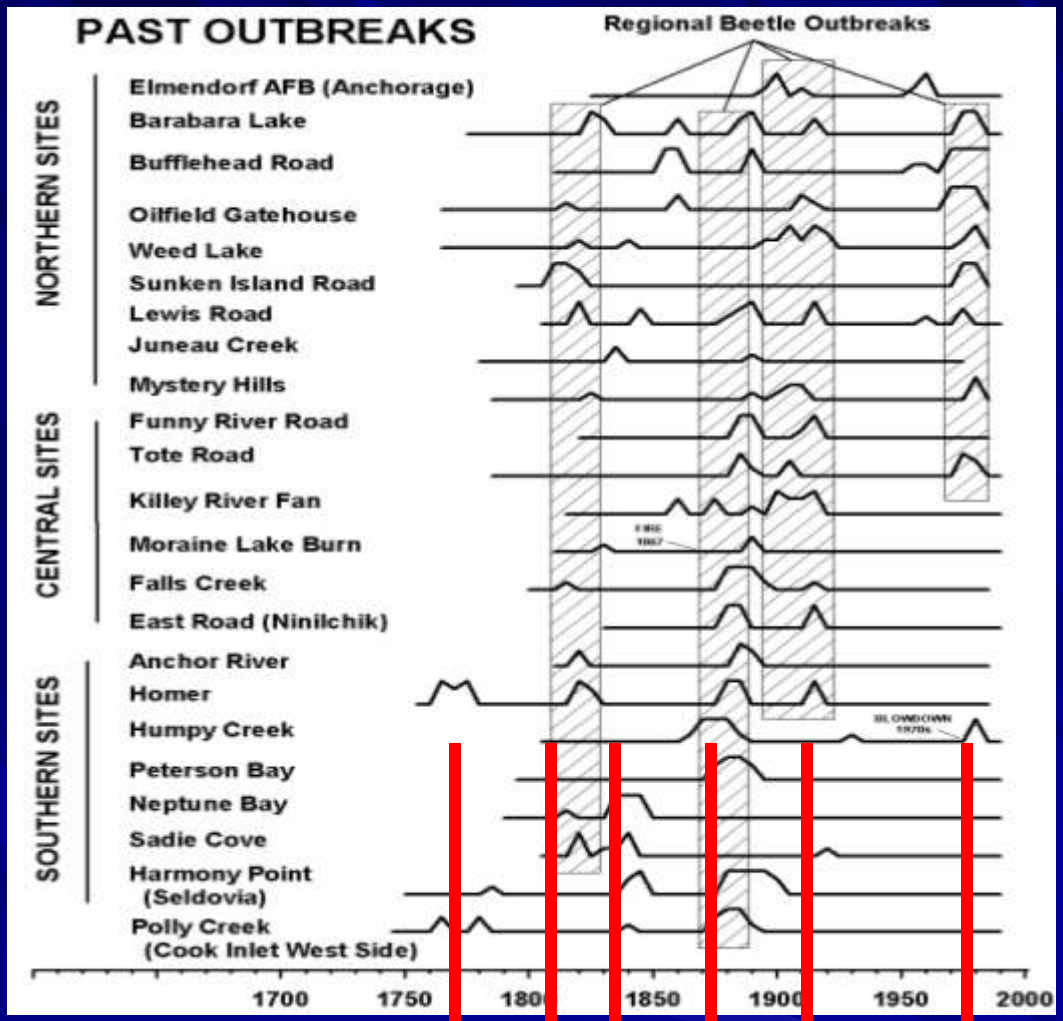
Amy Miller –
Southwest Alaska Network,
National Park Service

Lake Clark and Katmai Study Sites



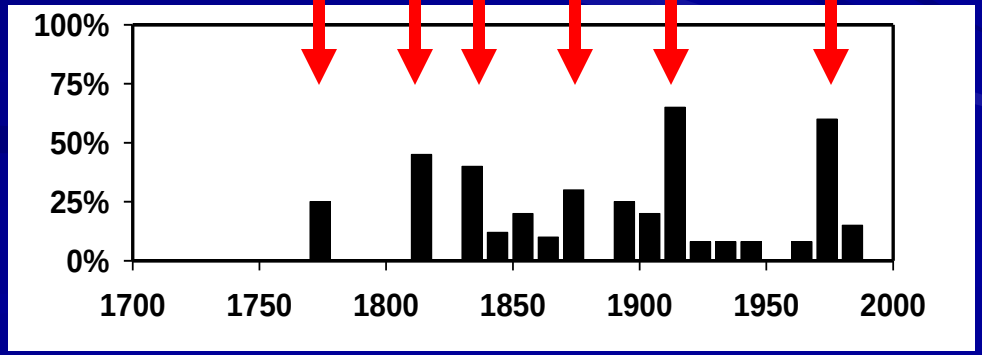
Both Sides of Cook Inlet Show the Same Outbreak Dates

Kenai Peninsula (22 sites)



Lake Clark And Katmai National Parks (15 sites)

Percent of Sites with Growth Releases



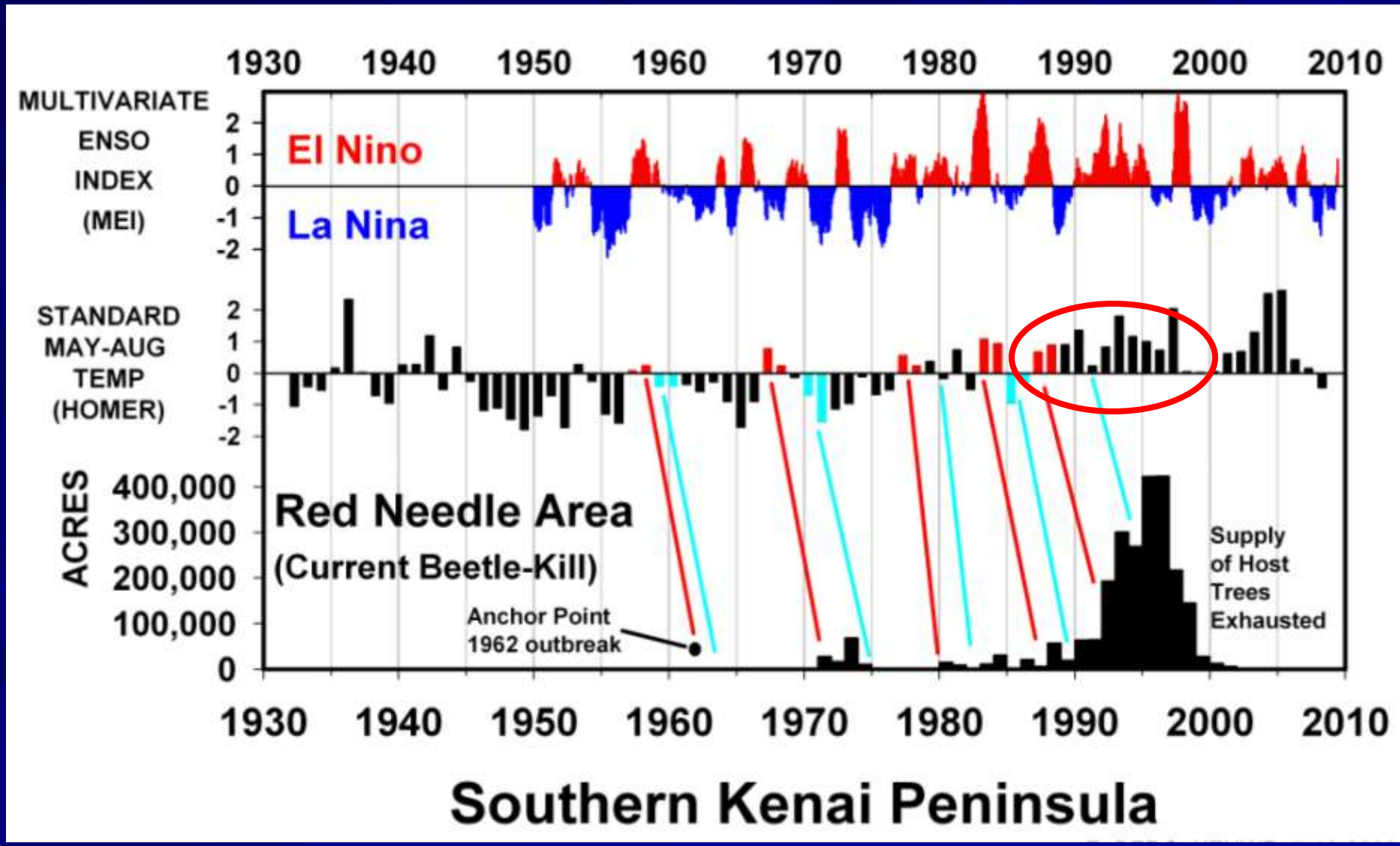
Bark Beetles and Runs of Warm Summers

Two factors are critical:

(1) A Loaded Gun – The forests must be mature or very mature

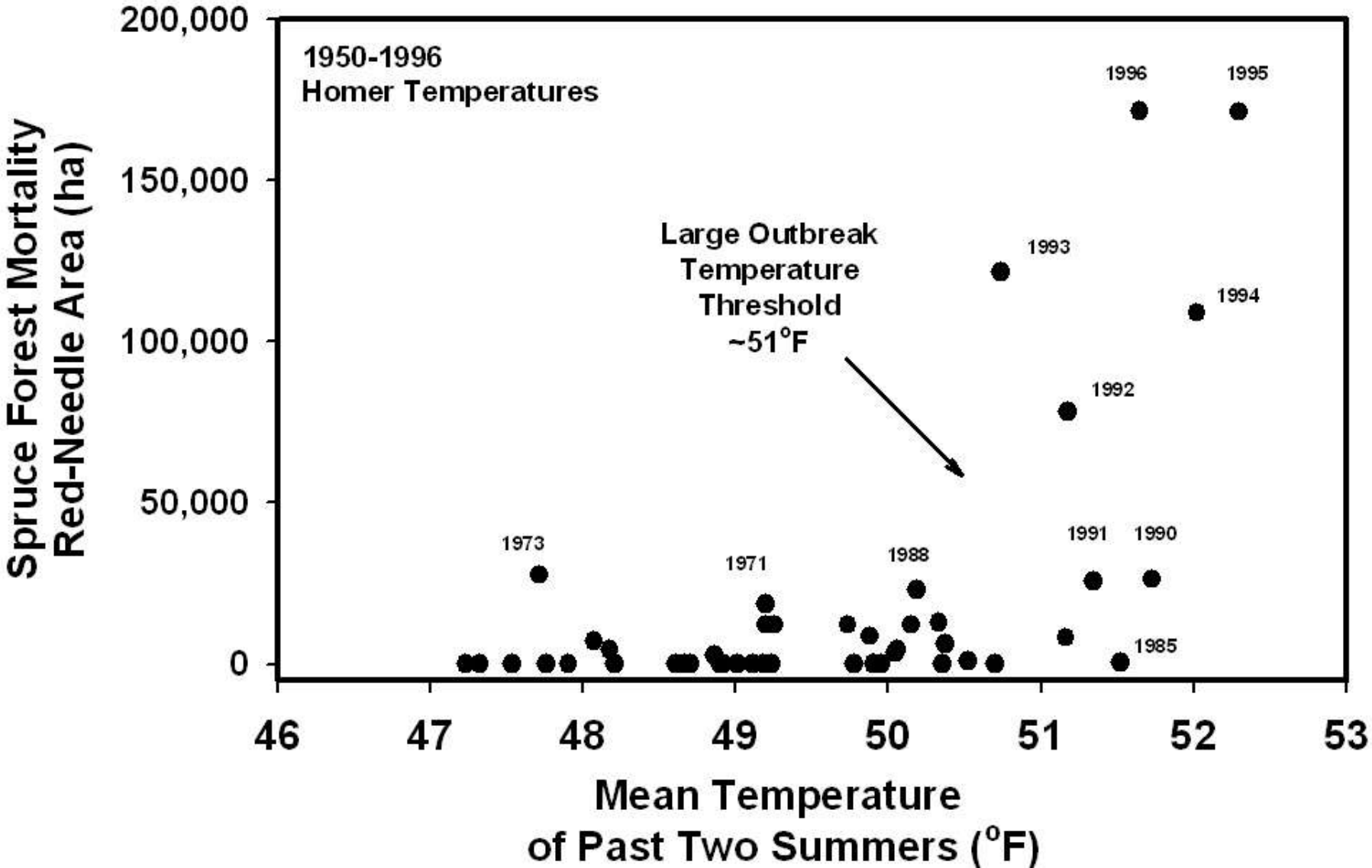
(2) A Trigger – a run of 2 or more warm summers can initiate an outbreak

Homer Runs of Warm and Cool Summers Track the El Niño-La Niña Cycle

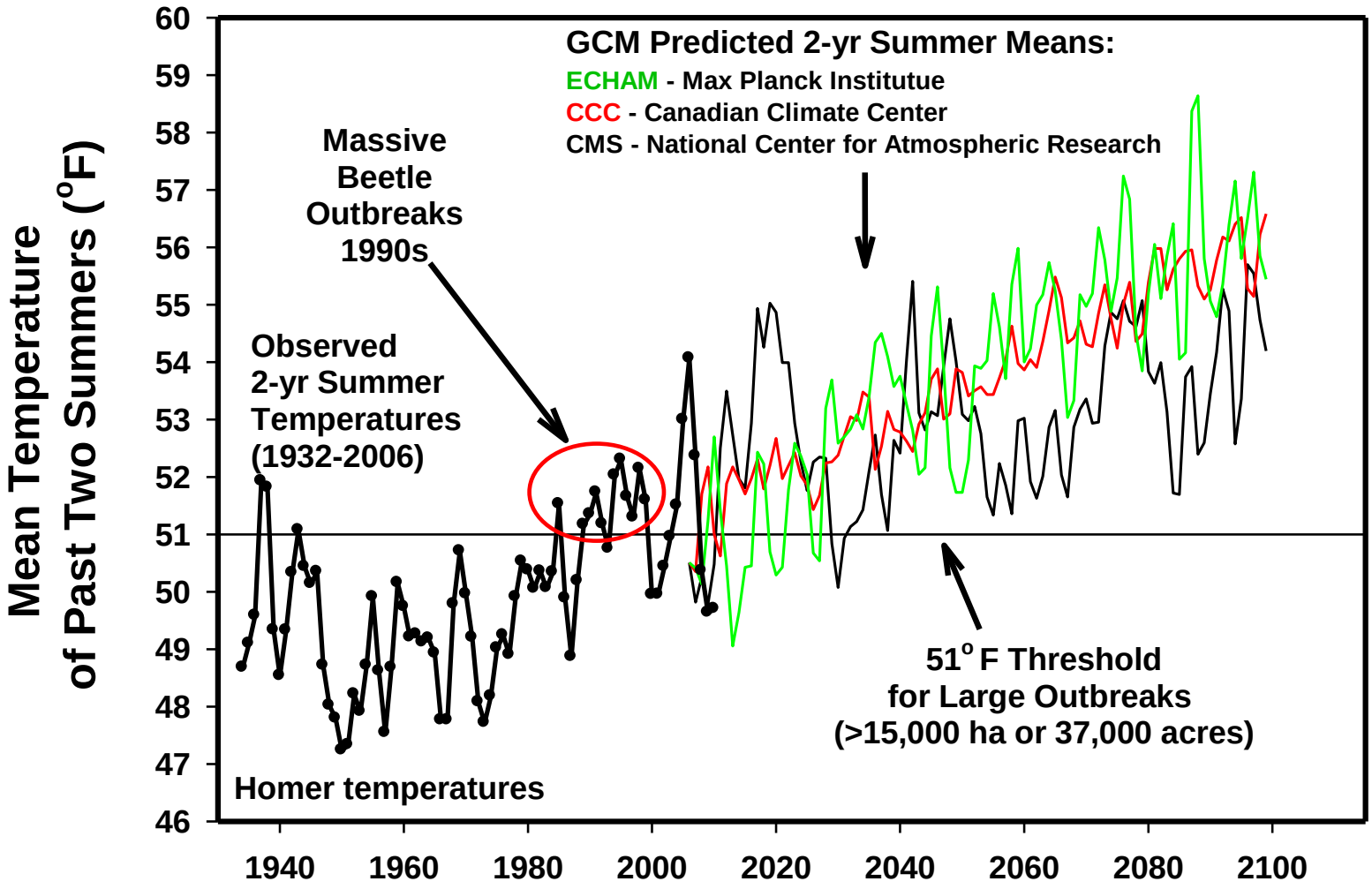


Spruce Bark Beetle Forest Mortality

Central-Southern Kenai Peninsula
and Kachemak Bay, Alaska



Predicted Summer Temperatures Will Keep Beetles at Large Outbreak Stage Whenever Mature Trees are Available

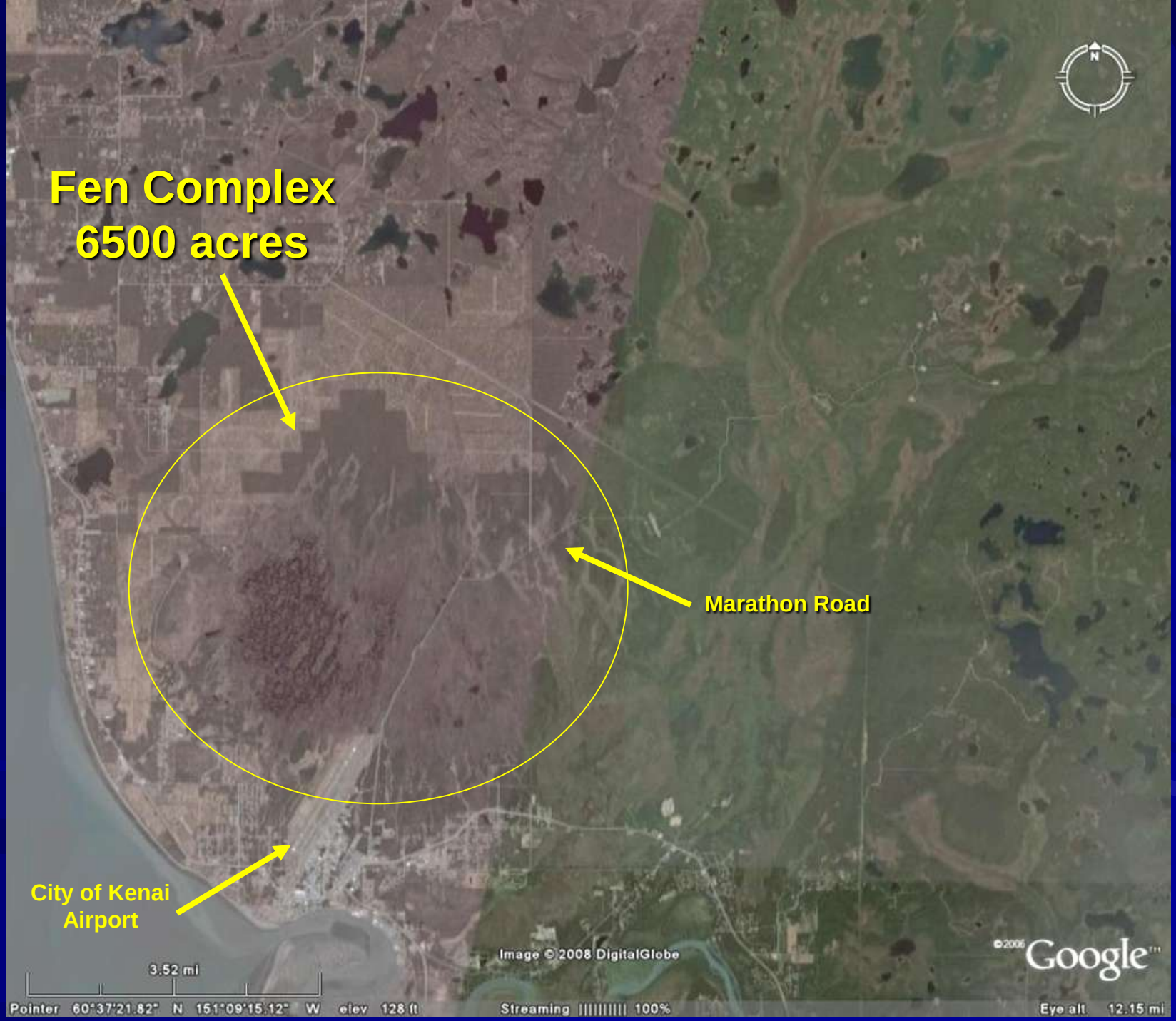


Drying Lakes & Wetlands

Jigsaw Lake
(a closed-basin lake)

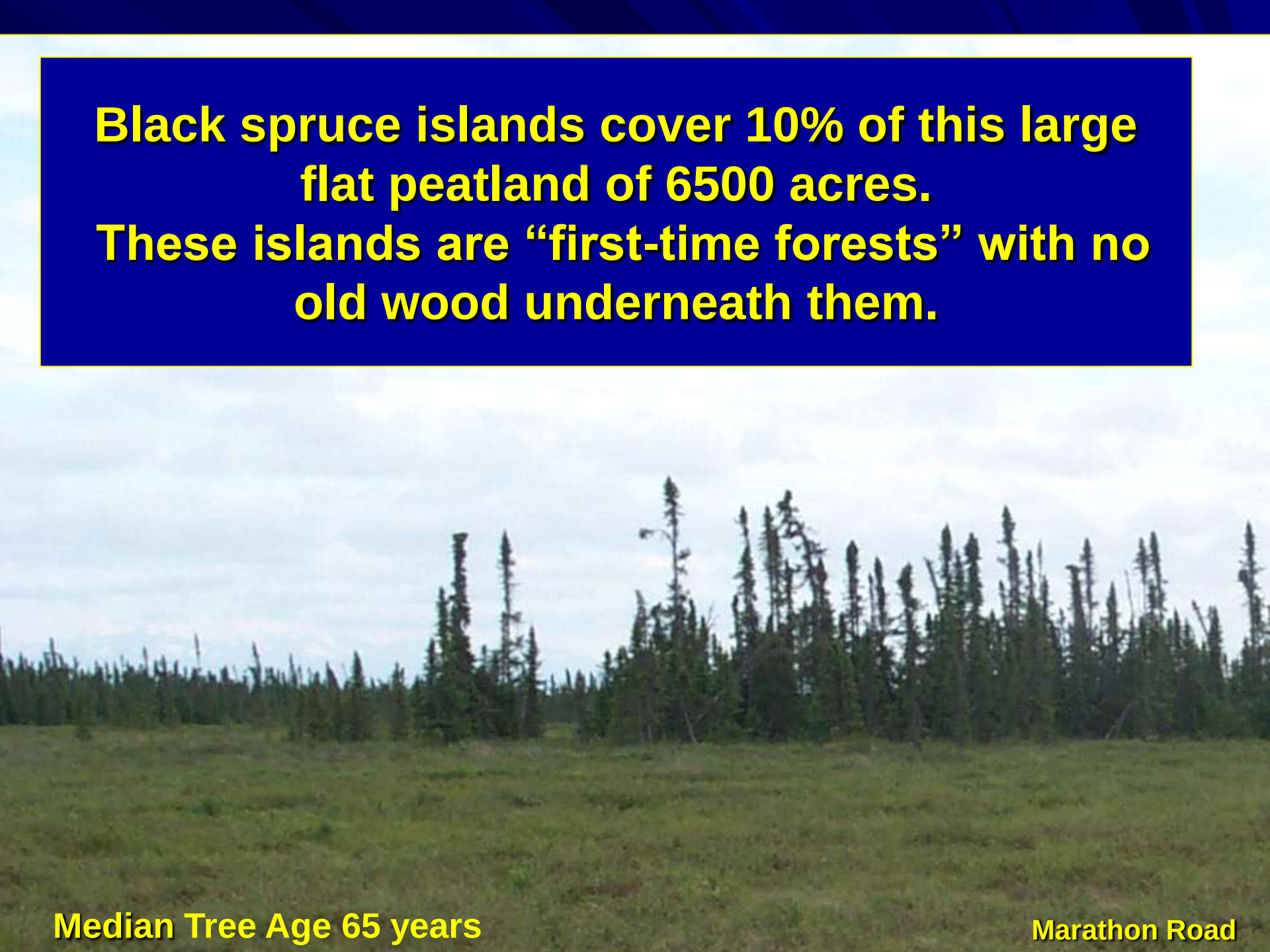
Jigsaw Lake
(a closed-basin lake)


Old Shoreline (1989)
Bulls-Eye Kettle
(a closed-basin pond)


Fen Complex
6500 acres
Marathon Road
City of Kenai
Airport
Image © 2008 DigitalGlobe
©2006 Google
3.52 mi
Pointer 60°37'21.82" N 151°09'15.12" W elev 128 ft
Streaming 100%
Eye alt 12.15 mi


Marathon Road
Black Spruce Islands
on the Fen Complex
Image © 2008 DigitalGlobe
©2006 Google
1020 ft
Pointer 60°36'20.42" N 151°11'34.42" W elev 120 ft
Streaming 100%
Eye alt 3640 ft

Black spruce islands cover 10% of this large flat peatland of 6500 acres.
These islands are “first-time forests” with no old wood underneath them.



Median Tree Age 65 years

Marathon Road

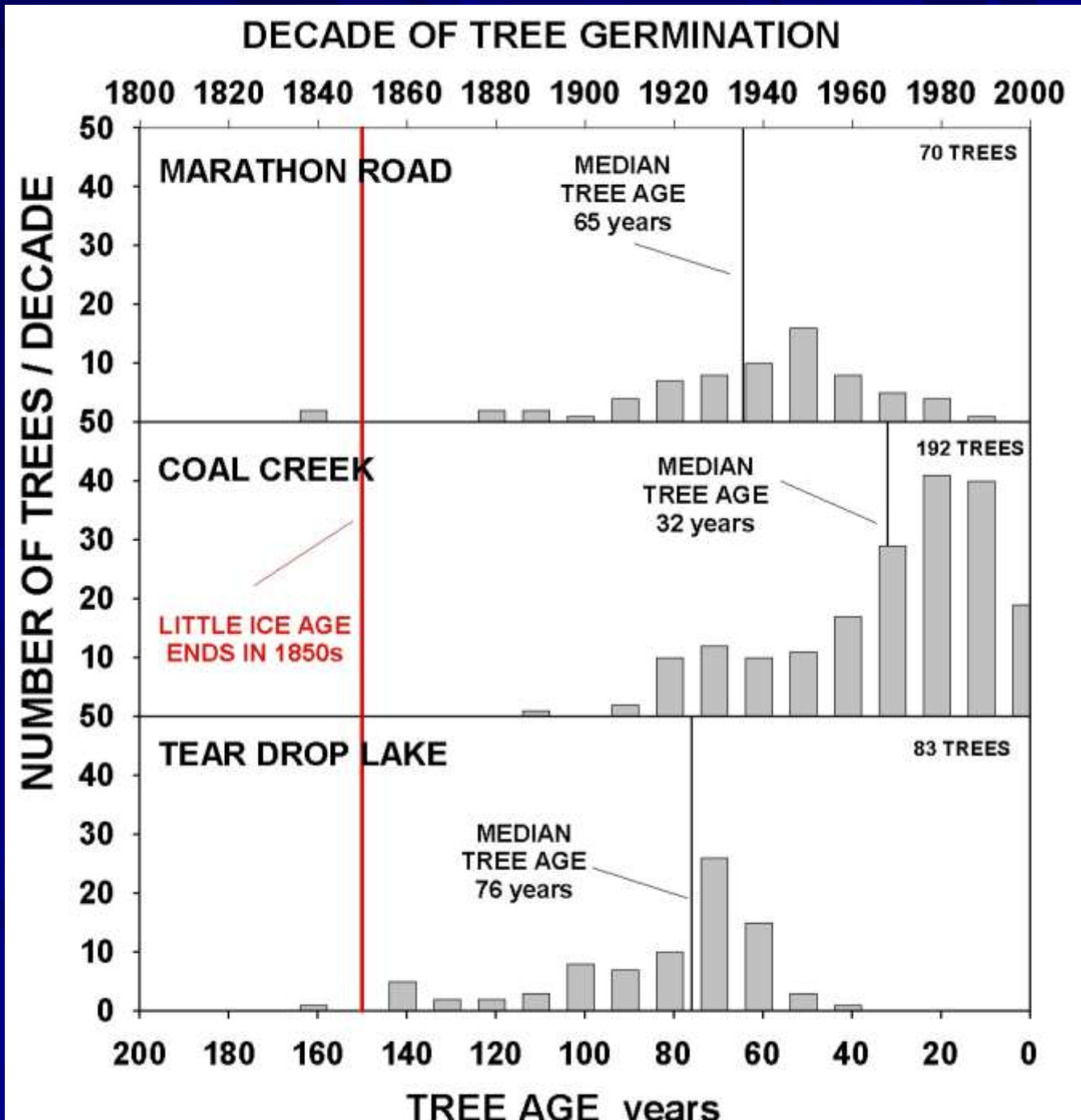

Marathon Road

Another Example: Coal Creek Muskeg

Median black spruce age is 32 years.

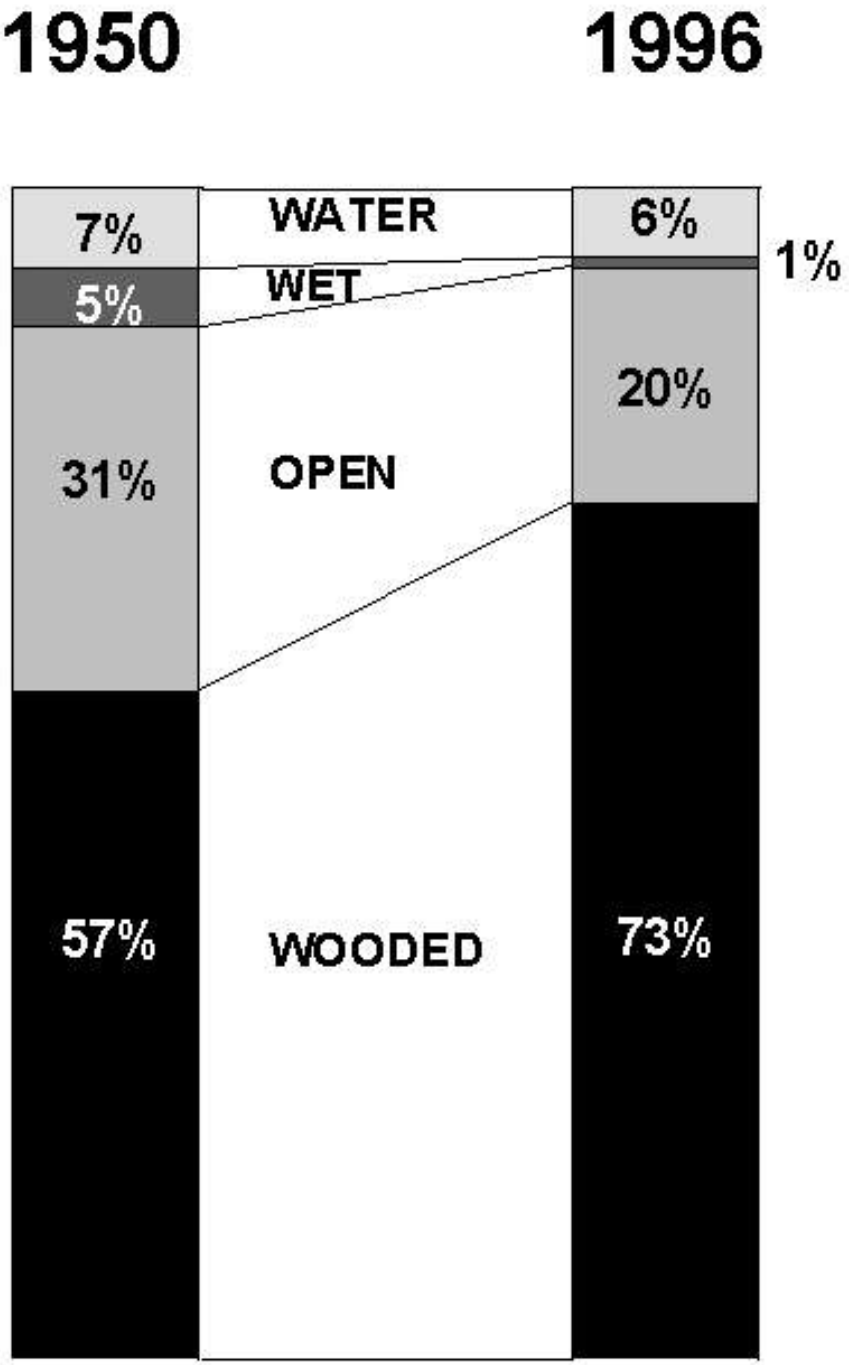
New forest is growing on top of >4 meters of *Sphagnum* peat.

Tree Age Summary of First-time Forests on Drying Peatlands



Aerial photo comparison of moisture/vegetation status at 1113 random points on the Kenai Lowlands:

Every category is drying out.



Eric Klein MS Thesis (APU) 2004

Wet *Sphagnum-Carex* fens

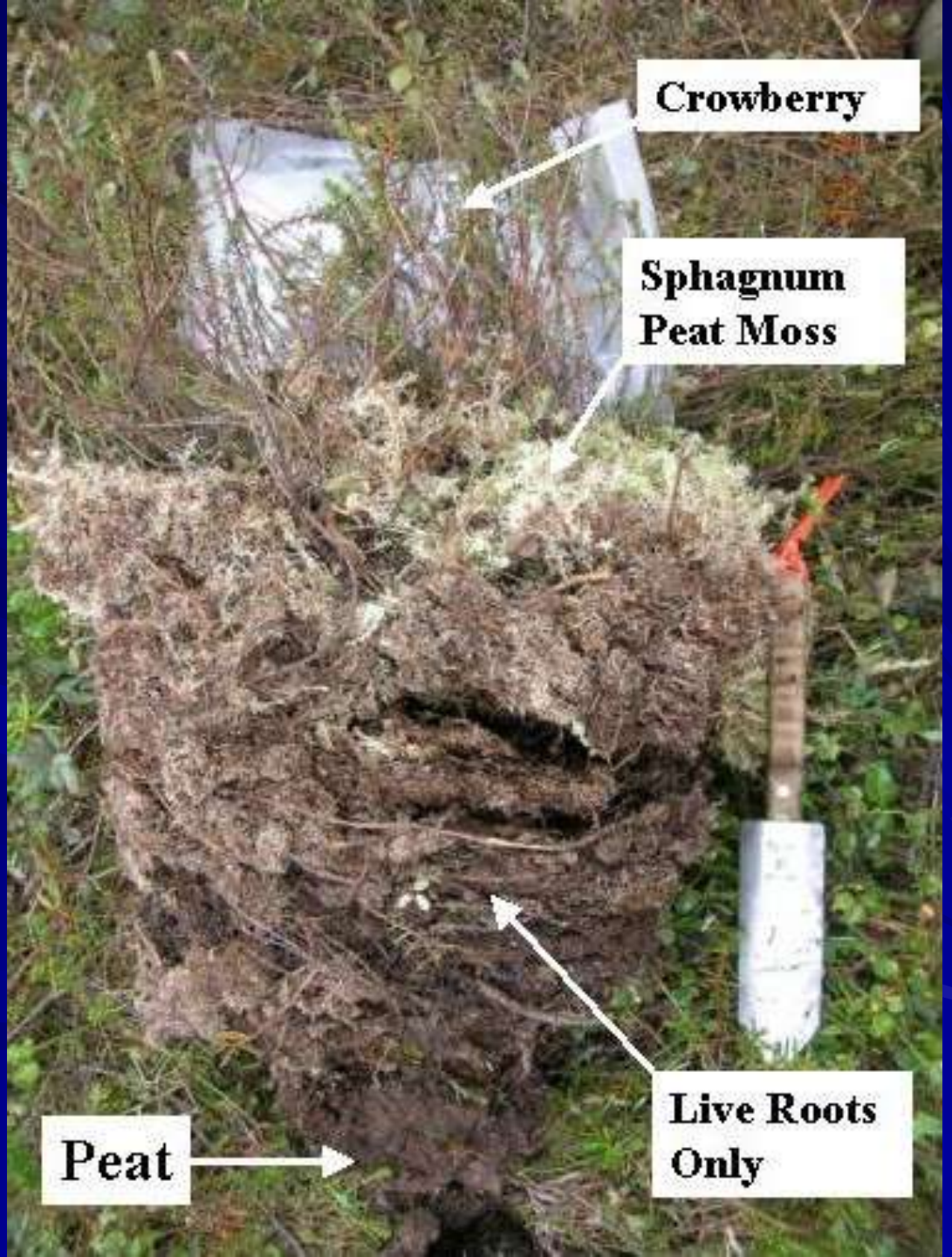

Shrubs


More Shrubs

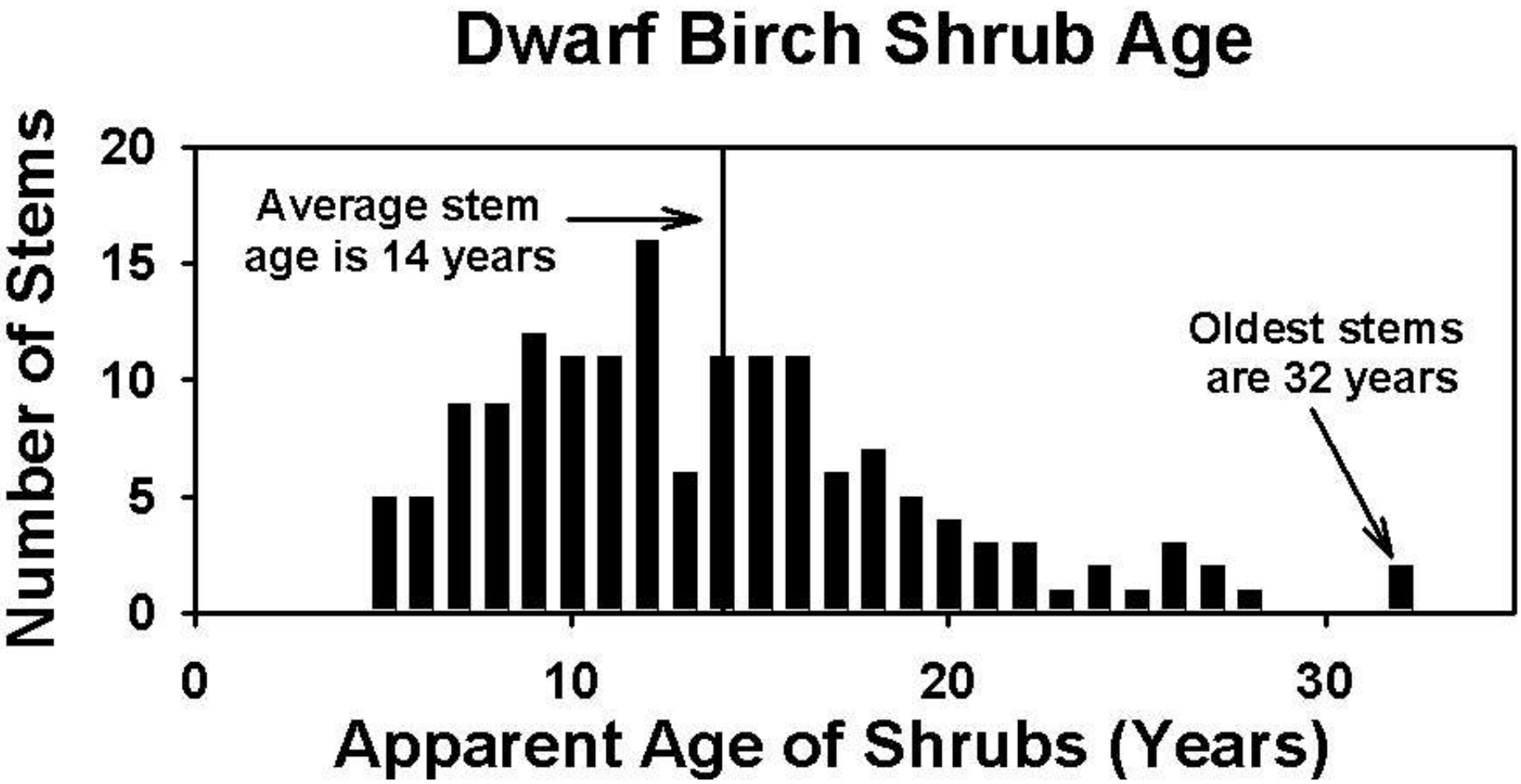

And Black Spruce

Shrub Invasion

No Dead Roots means Only New Plants



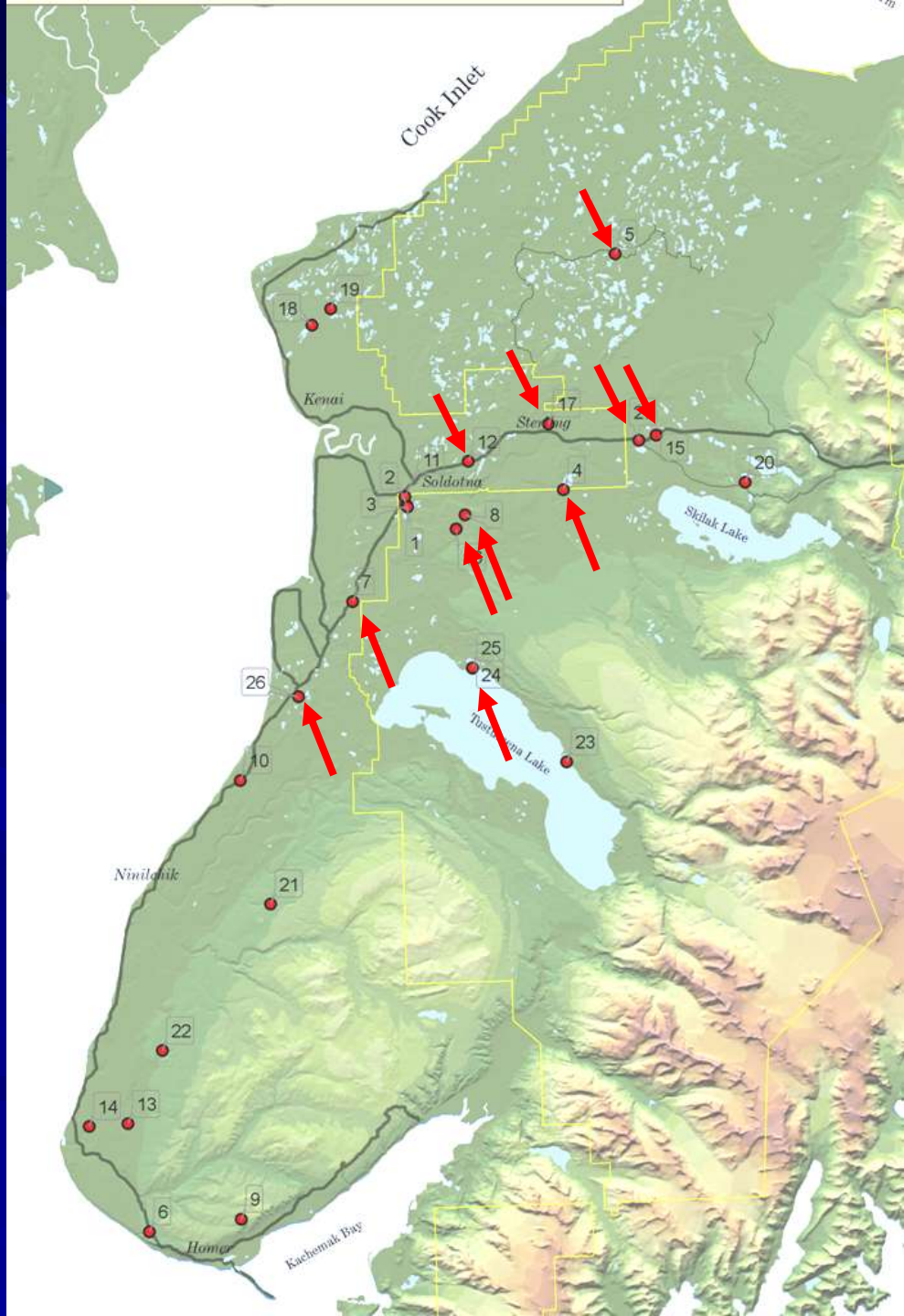
Dwarf Birch (*Betula nana*)



3 Tree-ring Sites

Study Sites

- 26 Peat Core Sites
- 11 Aerial Photo Sites
- 3 Tree-ring Sites



Aerial Photo Study: Two Approaches

(1) Wetland edge ecotones: classification of vegetation on points on a rectangular grid

(2) Whole wetlands: digitized herbaceous edges

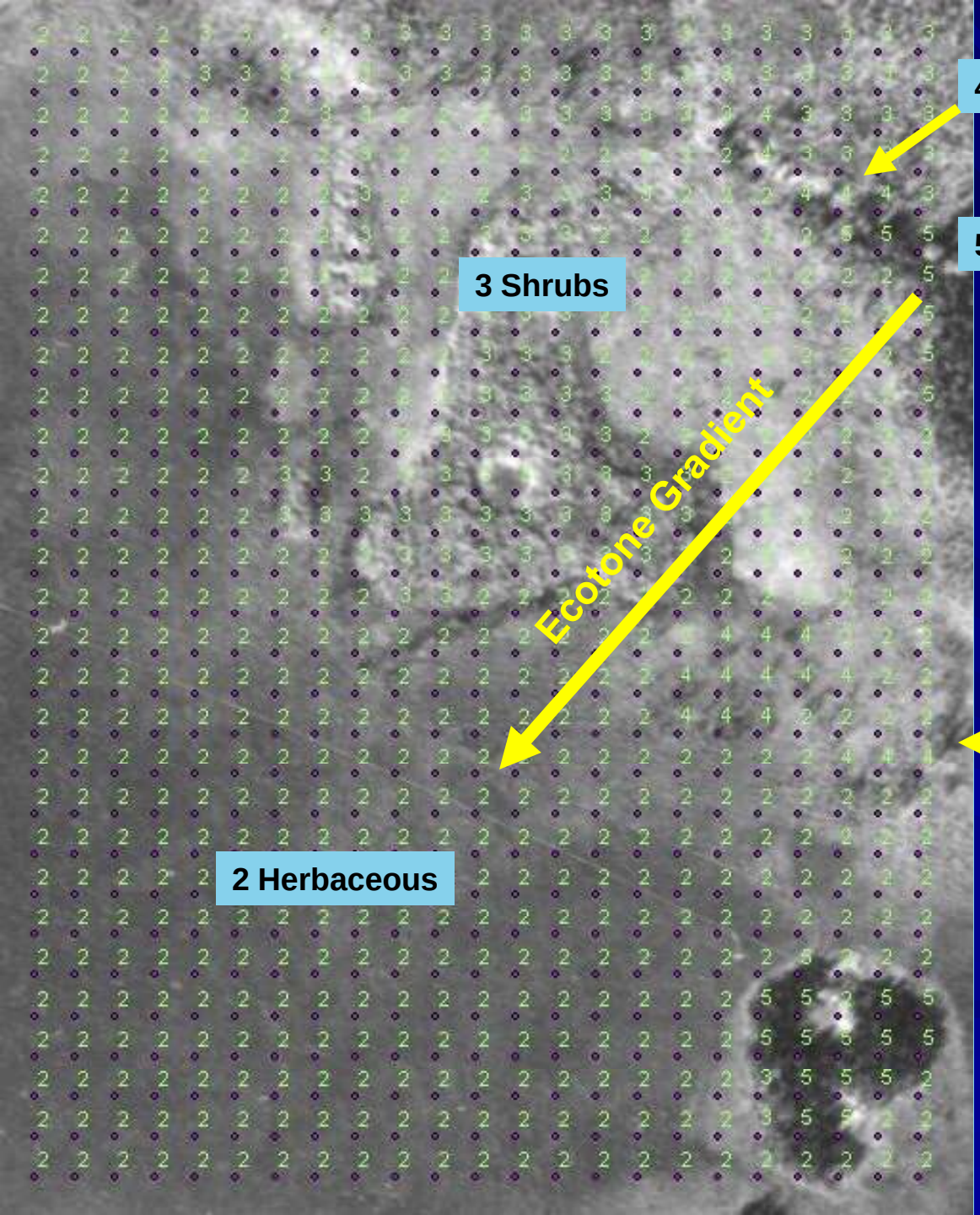
Kacy McDonnell MS Thesis (APU) 2007

1st Approach: Wetland Edge Ecotones

Cover Classes:

1 - Open Water
2 - Herbaceous
3 - Shrubs
4 - Open Woodland
5 - Closed Canopy Forest

600 points classified on each photo: 1951, 1968, and 1996

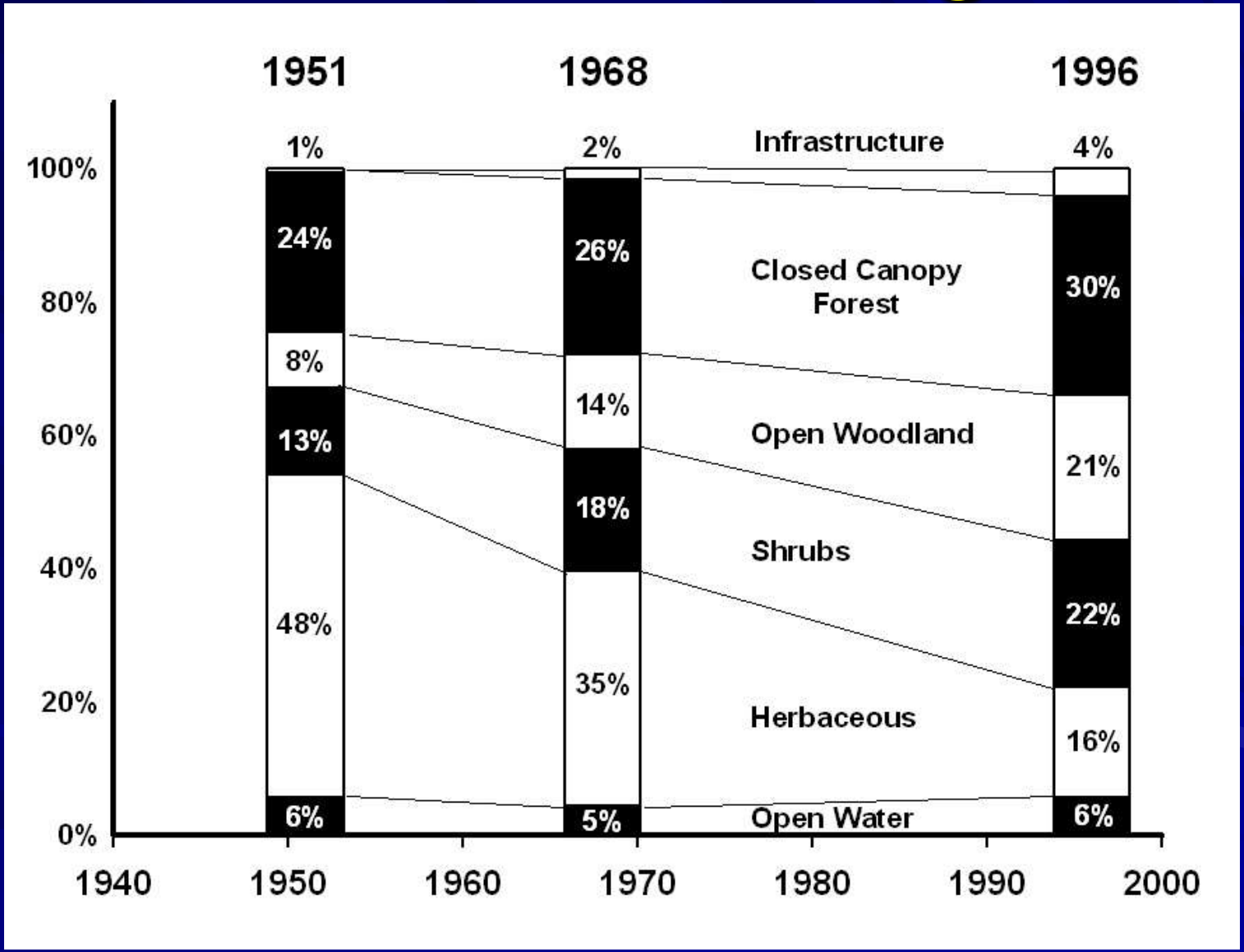


Brown's Lake Fen

15 meters between grid points

Points are classified on 1951, 1968 & 1996 aerial photos

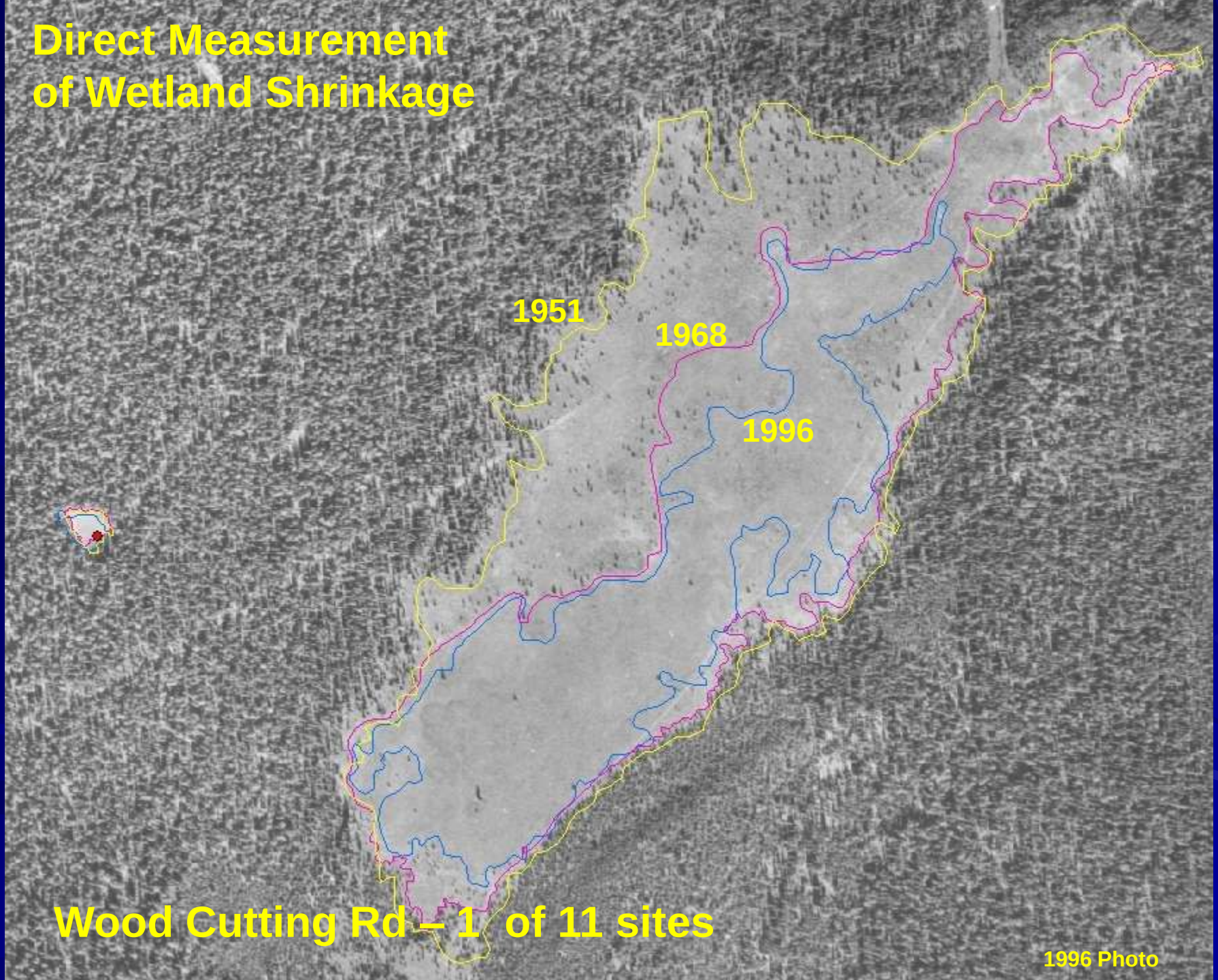
Ecotone Change



11 sites pooled

2nd Approach: Measuring Whole Wetland Areas

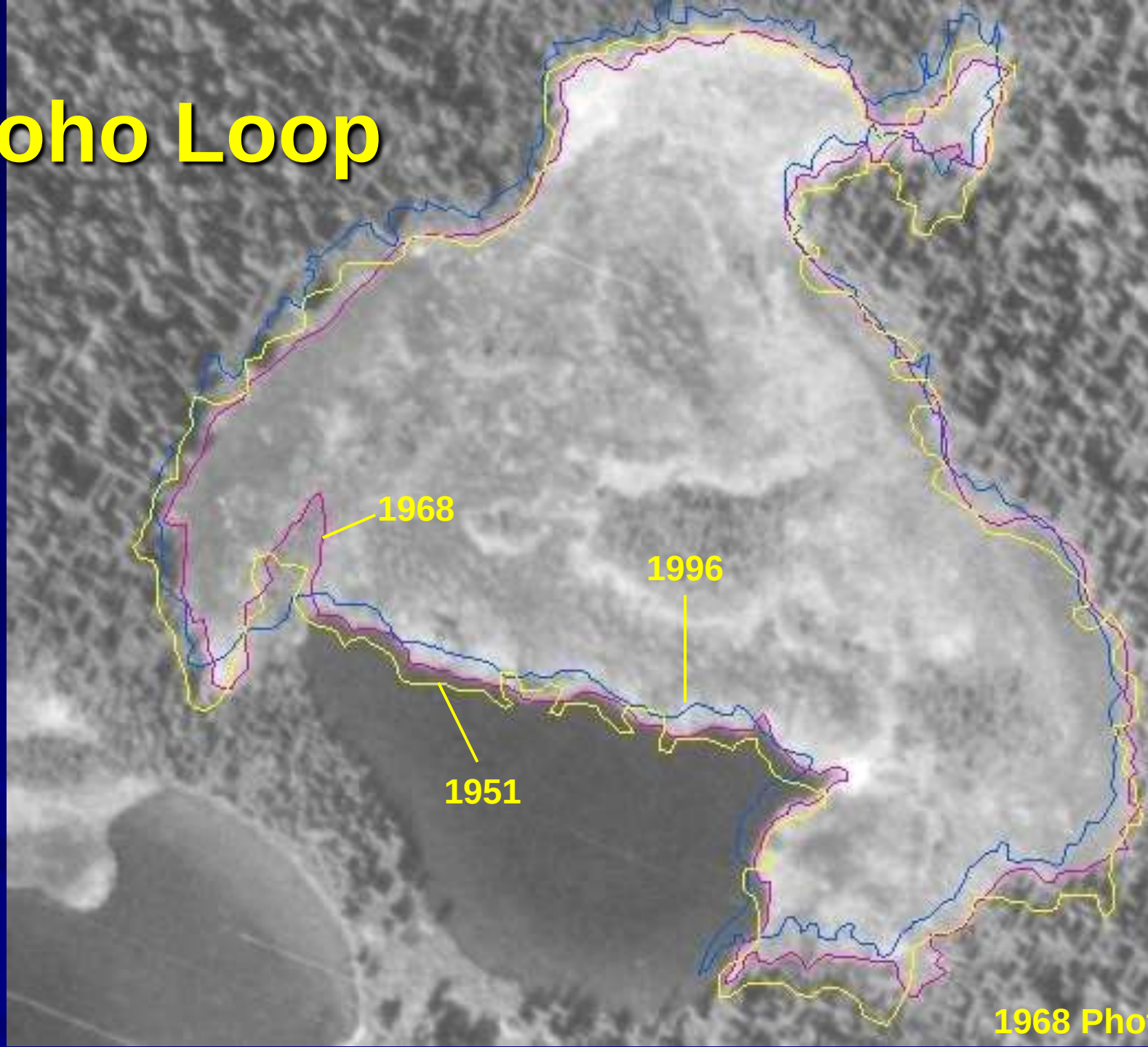
Direct Measurement of Wetland Shrinkage

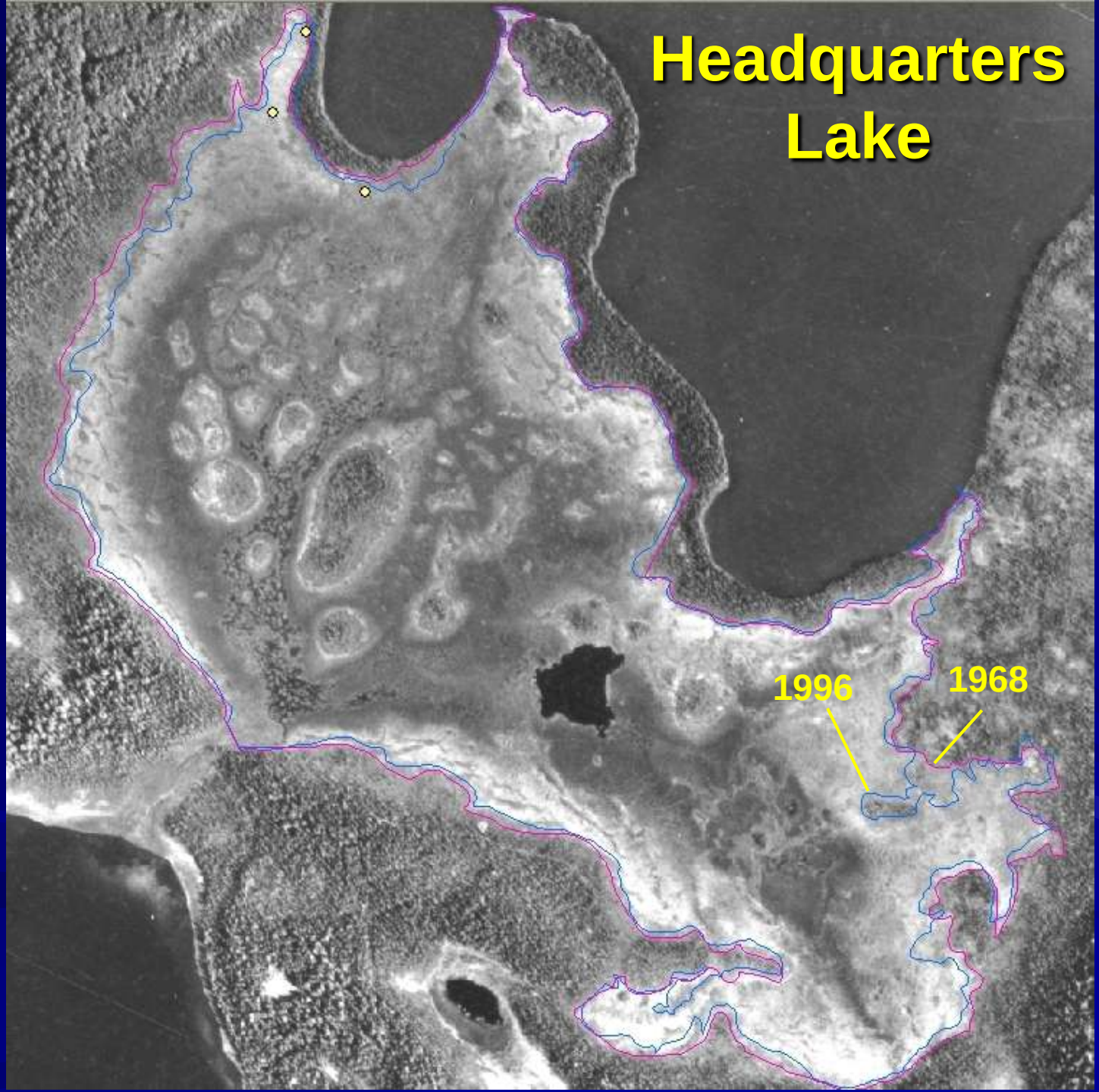


Wood Cutting Rd – 1 of 11 sites

1996 Photo

Coho Loop





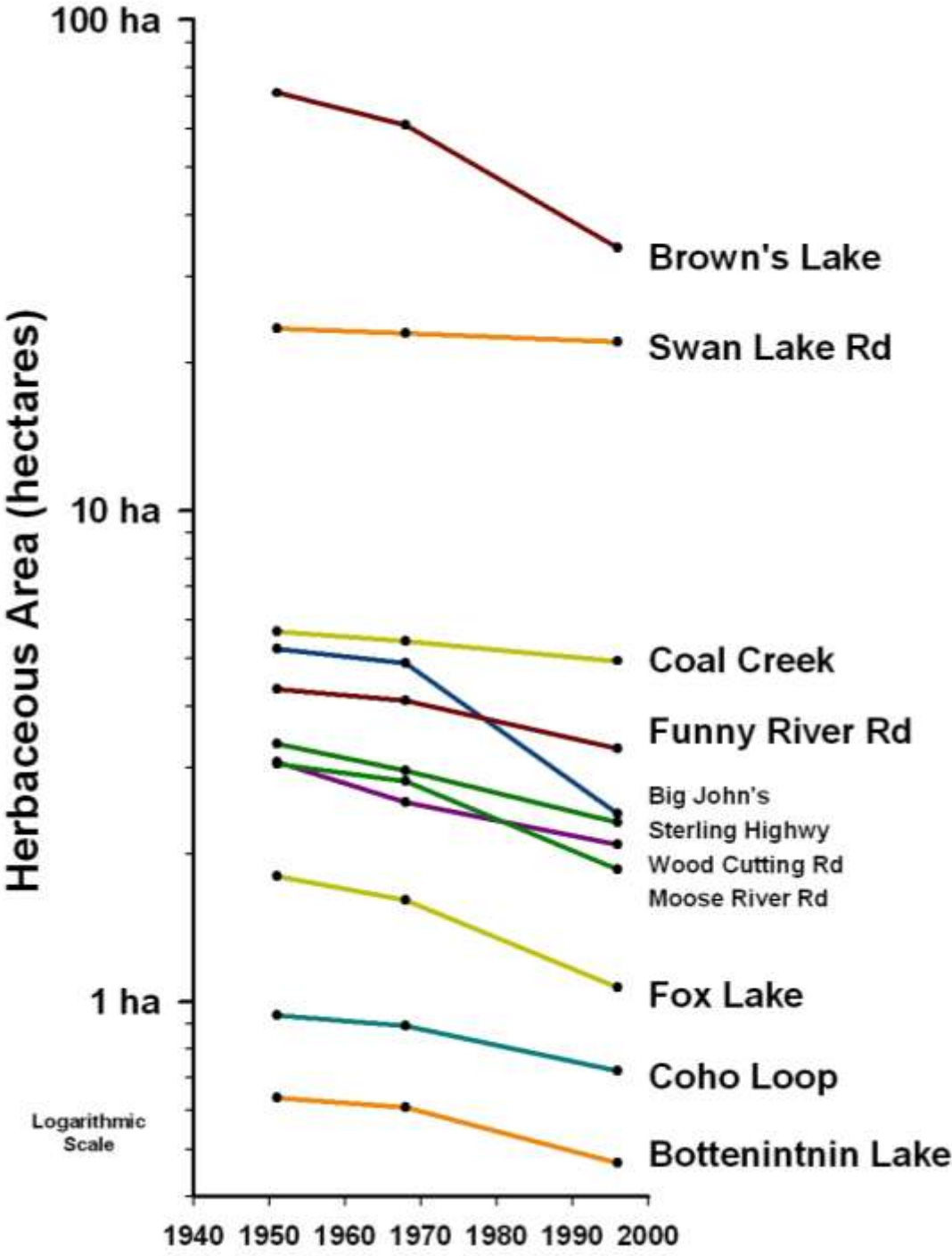
1996 Photo

Herbaceous Wetland Loss

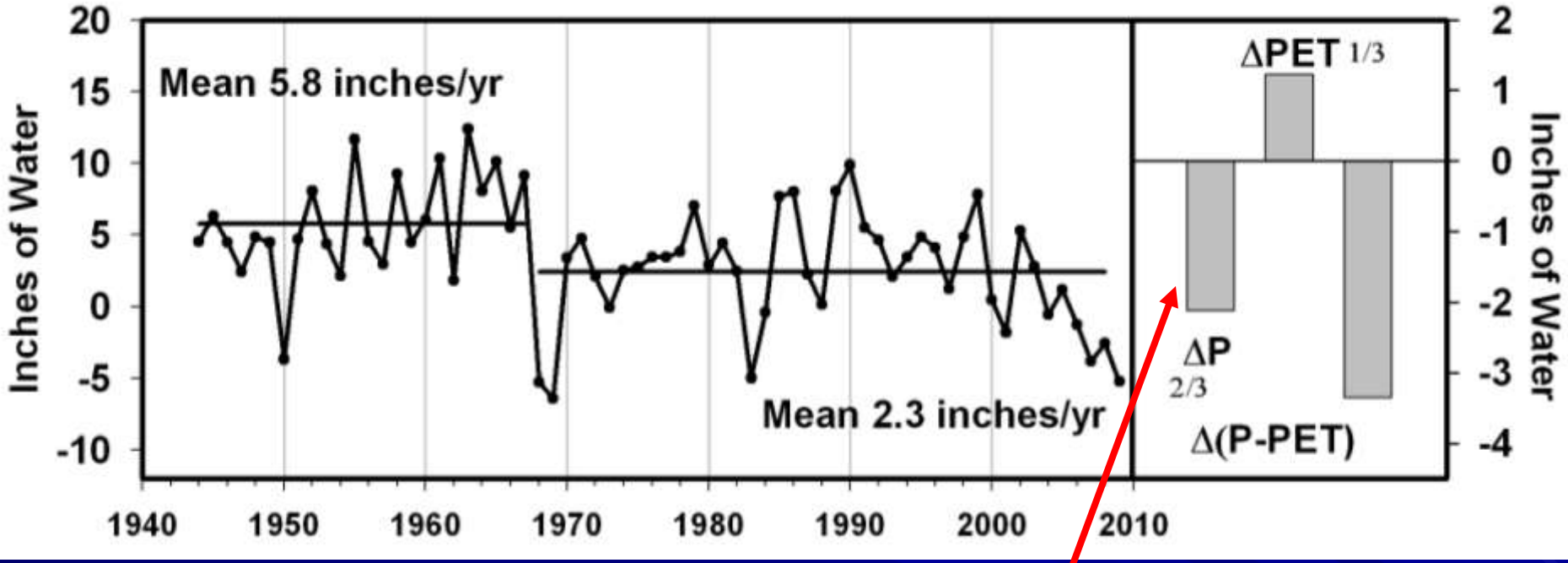
Rates of Area Change:

1951-1968:
6.2 % loss/decade

1968-1996:
11.1 % loss/decade



Kenai Water Balance (P – PET)

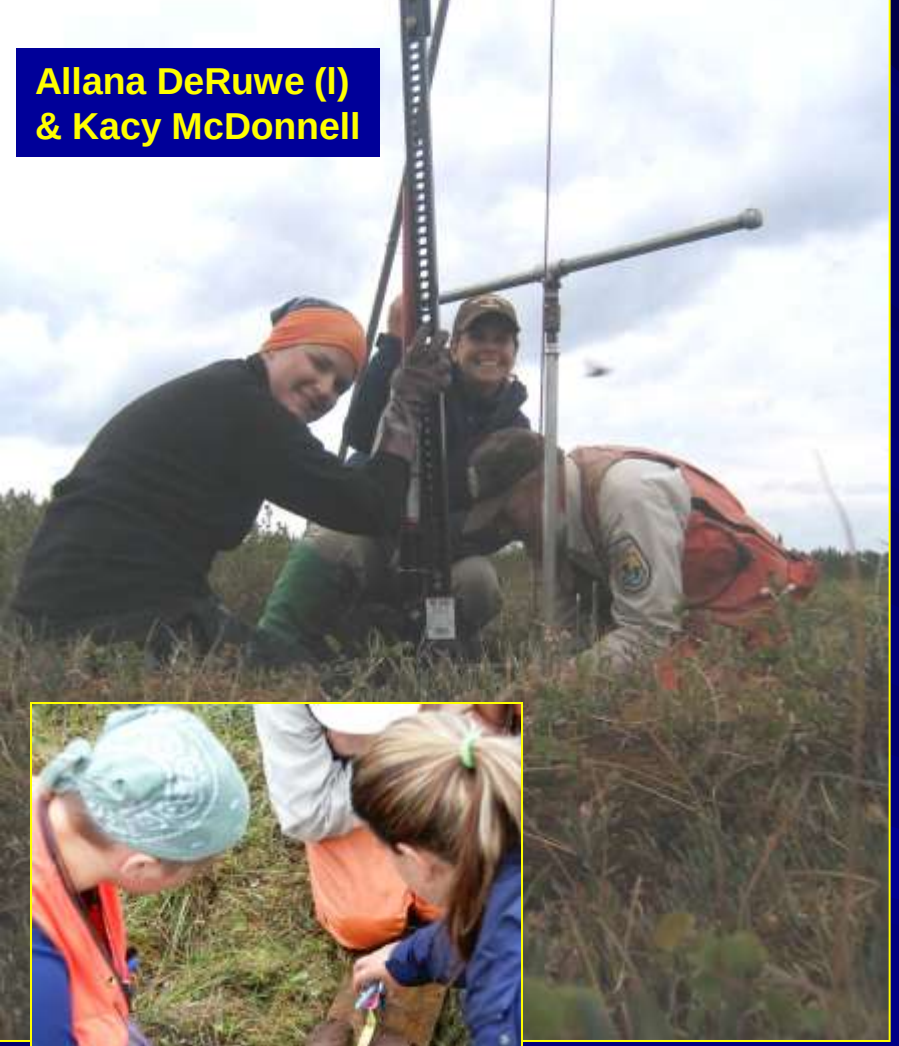


1 – 2.3/5.8 = 1 – 0.40 = 60% Decline in available water

Decline in precipitation P is about twice the increase in evapotranspiration (PET)

Potential Evapotranspiration (PET) is calculated by the Thornthwaite-Mather method from monthly air temperature.

Peat Coring



Allana DeRuwe (l)
& Kacy McDonnell

Peat Coring

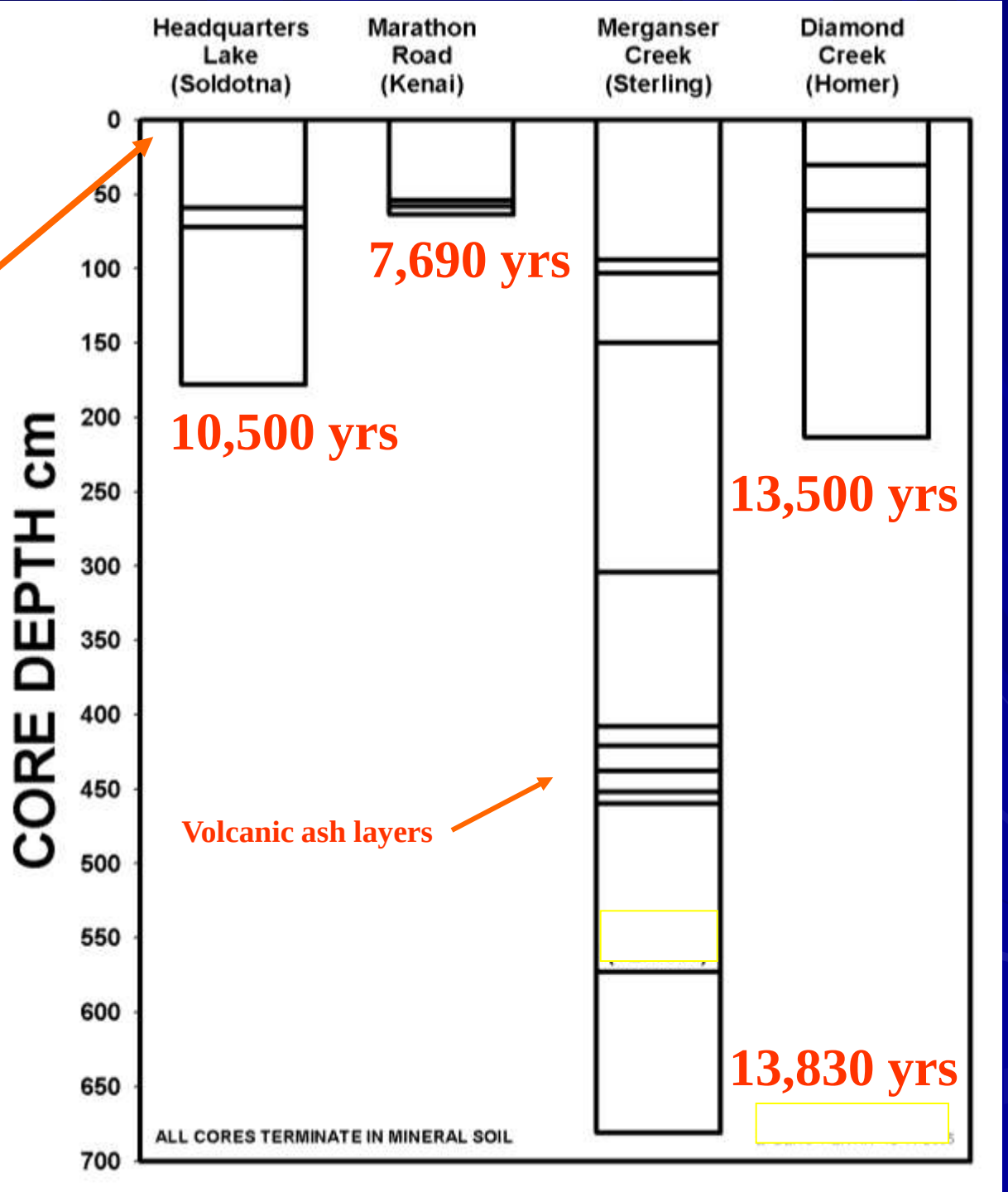
Monoliths


Top (below monolith)
Middle section
Lower section
3 in
Glacial mud
~19,000 years old

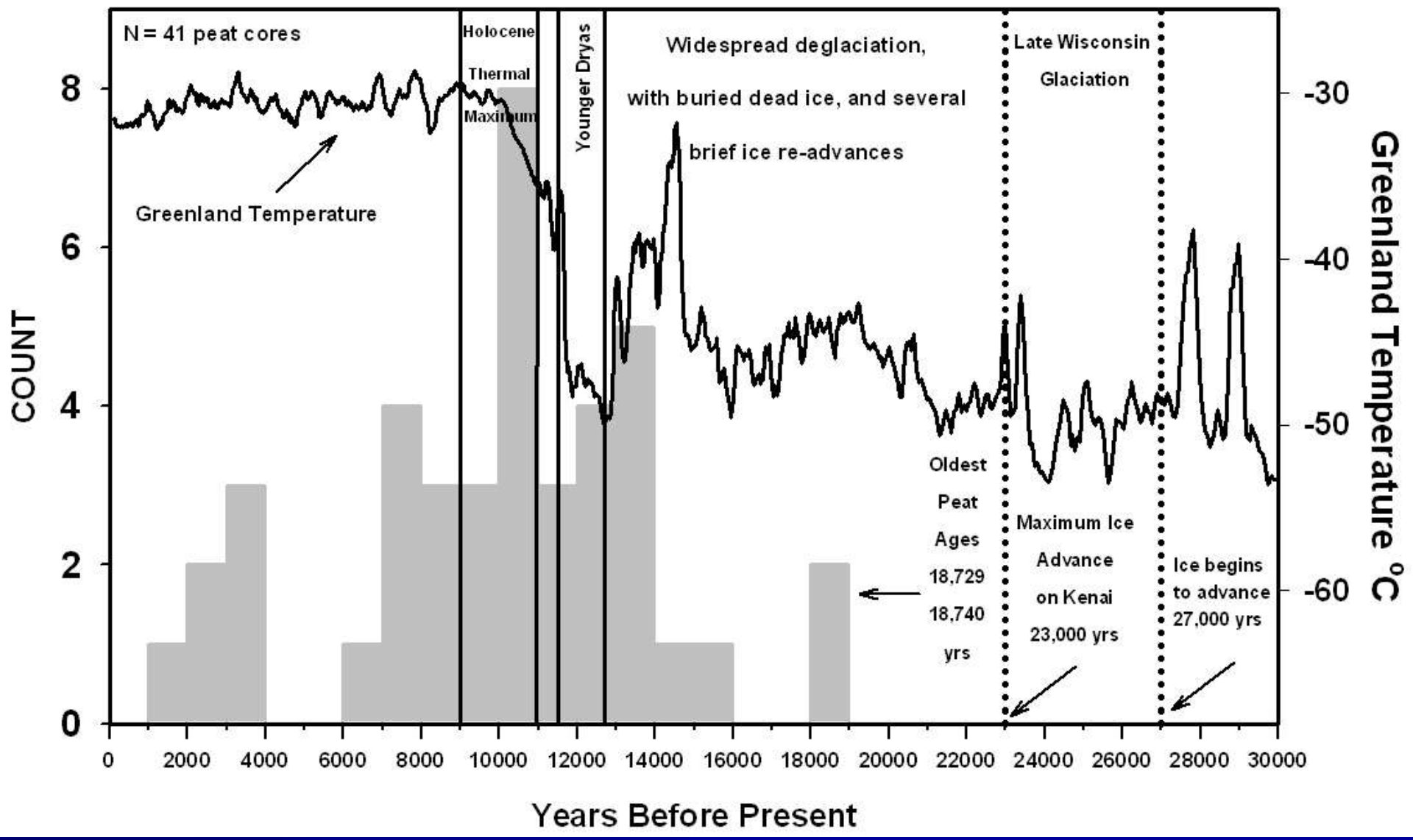
Peat Cores

Woody material is only at the top.

***Sphagnum*-sedge peat is below.**



Histogram of Basal Peat Ages



Take-Home Message:

Kenai Wetlands Show Extreme Recent Drying

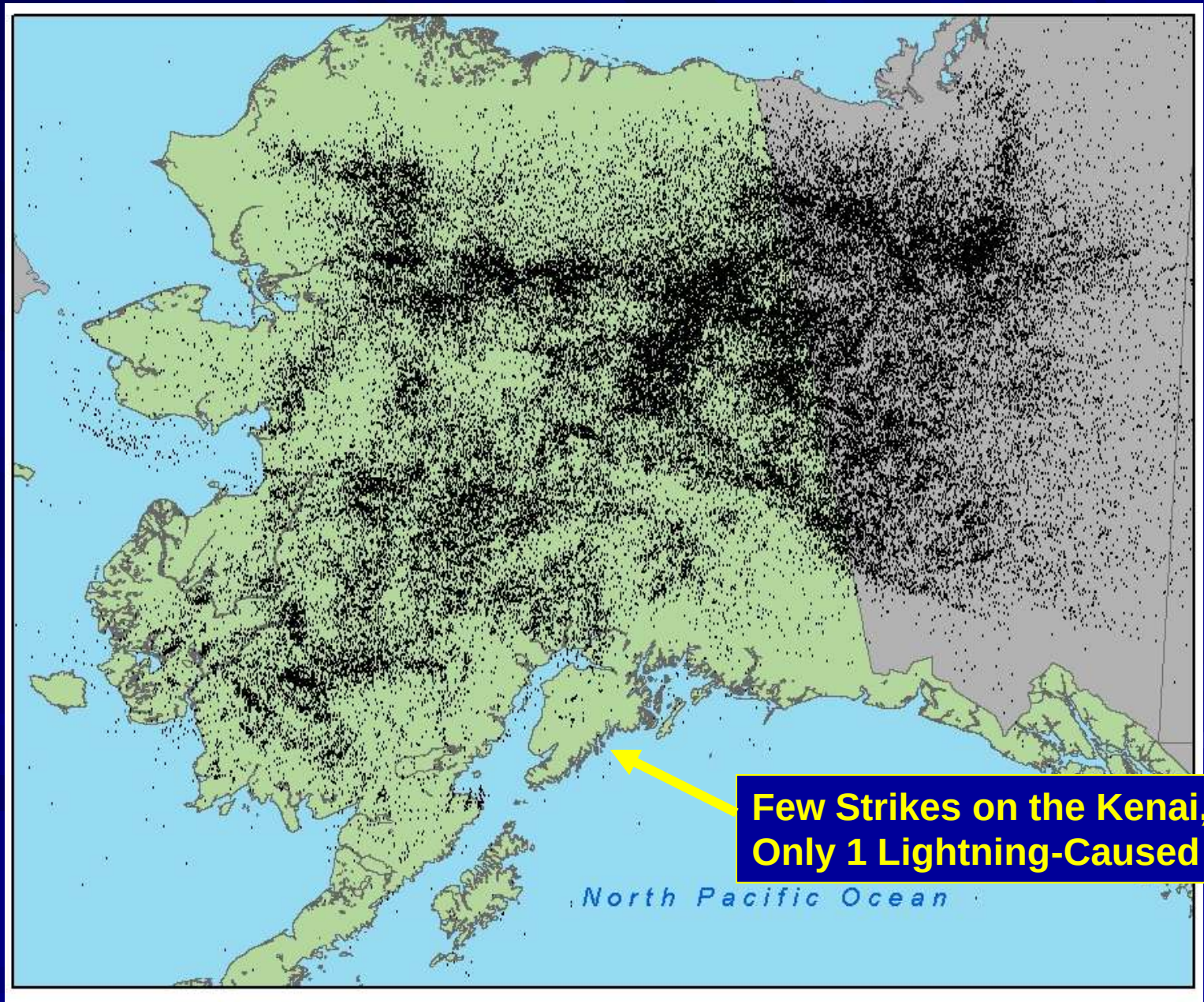
- **Peat cores show ~ 19,000 years of wet *Sphagnum*-sedge fen environment, with recent shrub invasion.**
- **Climate drying started at end of Little Ice Age in 1850s.**
- **Drying has accelerated since 1970s.**

Changing Fire Regimes

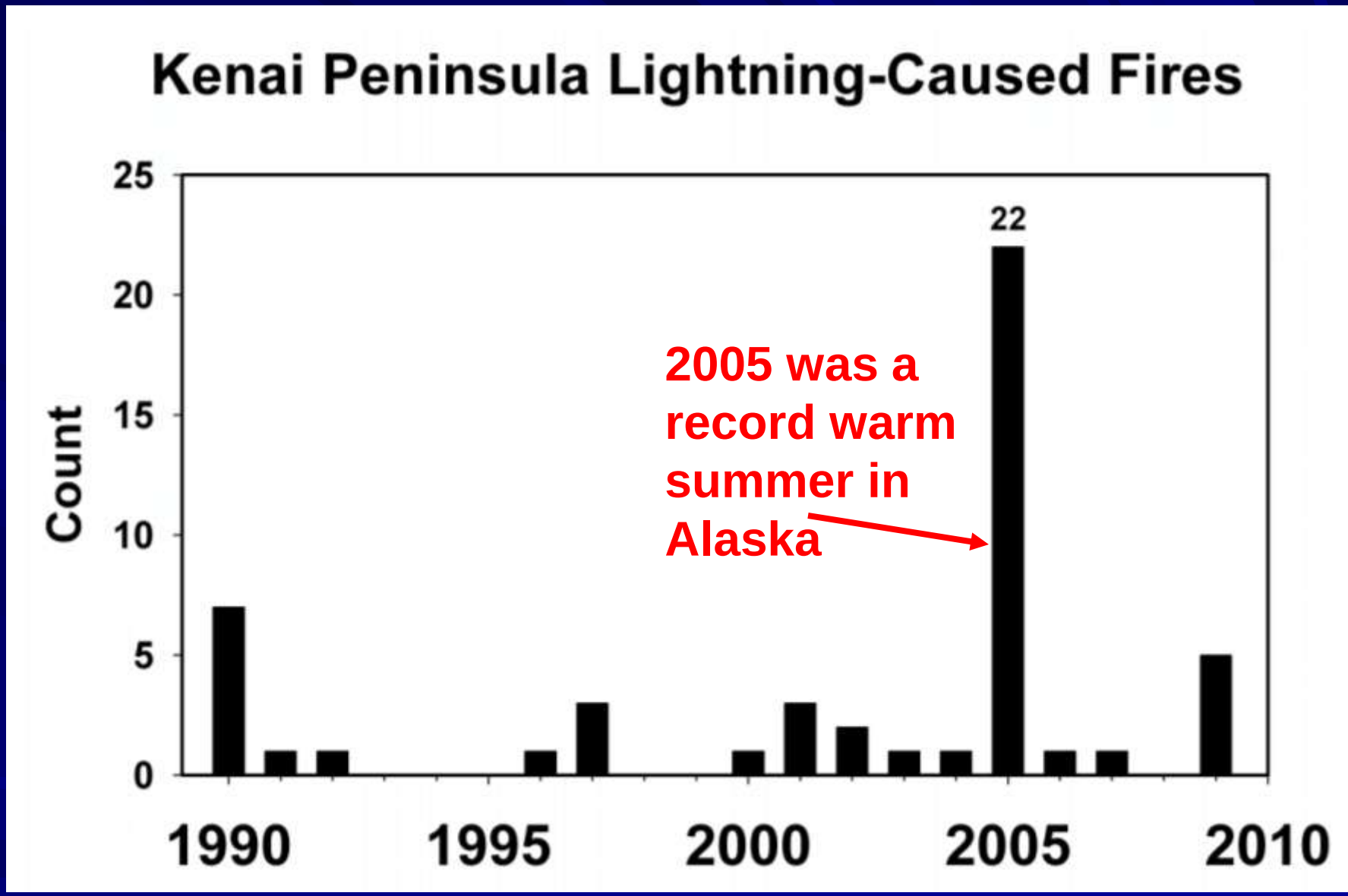
Three Fire Regimes

FOREST TYPE	METHOD	FIRE RETURN INTERVAL
Black Spruce	Fire Scars (300 yr record)	80 years
Mixed White Spruce & Hardwoods	Lake Sediment Charcoal (13,000 yr record)	130 years
White/Lutz Spruce	Soil Charcoal (5000 yr record)	500 years

Lightning Strikes 2002 – A Normal Year

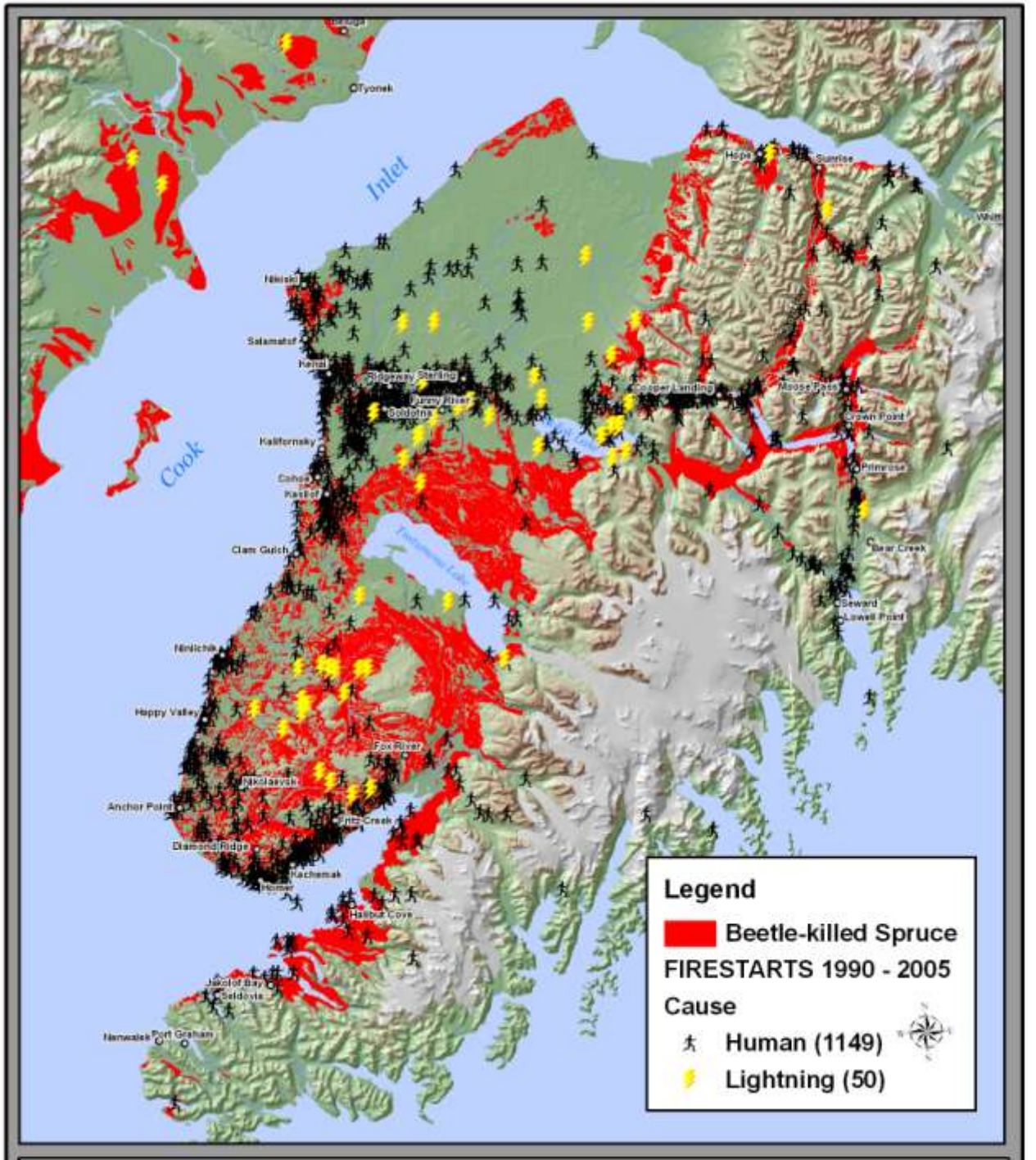


**Few Strikes on the Kenai,
Only 1 Lightning-Caused Fire**



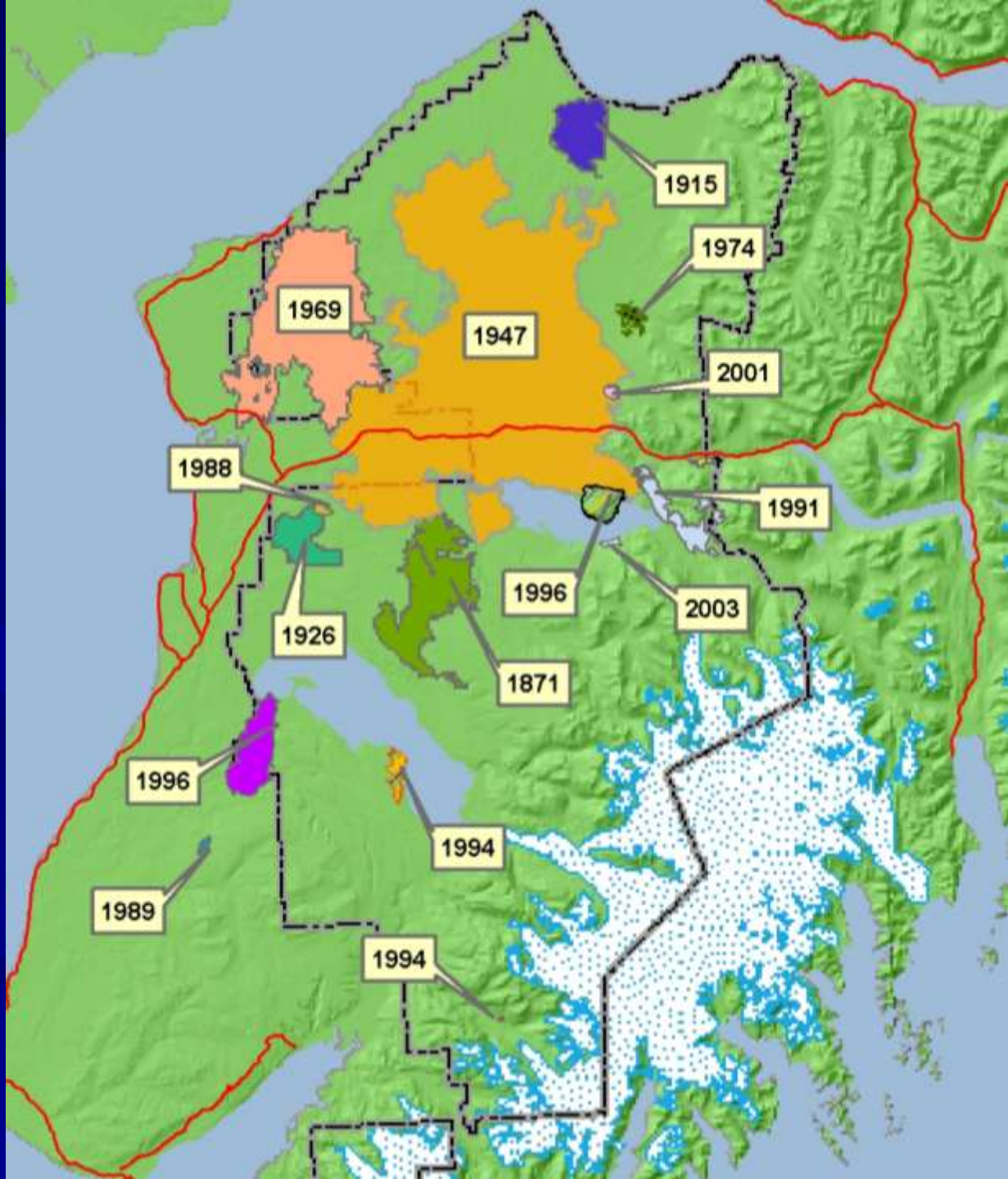
Lightning is a new wildcard in the climate change deck.

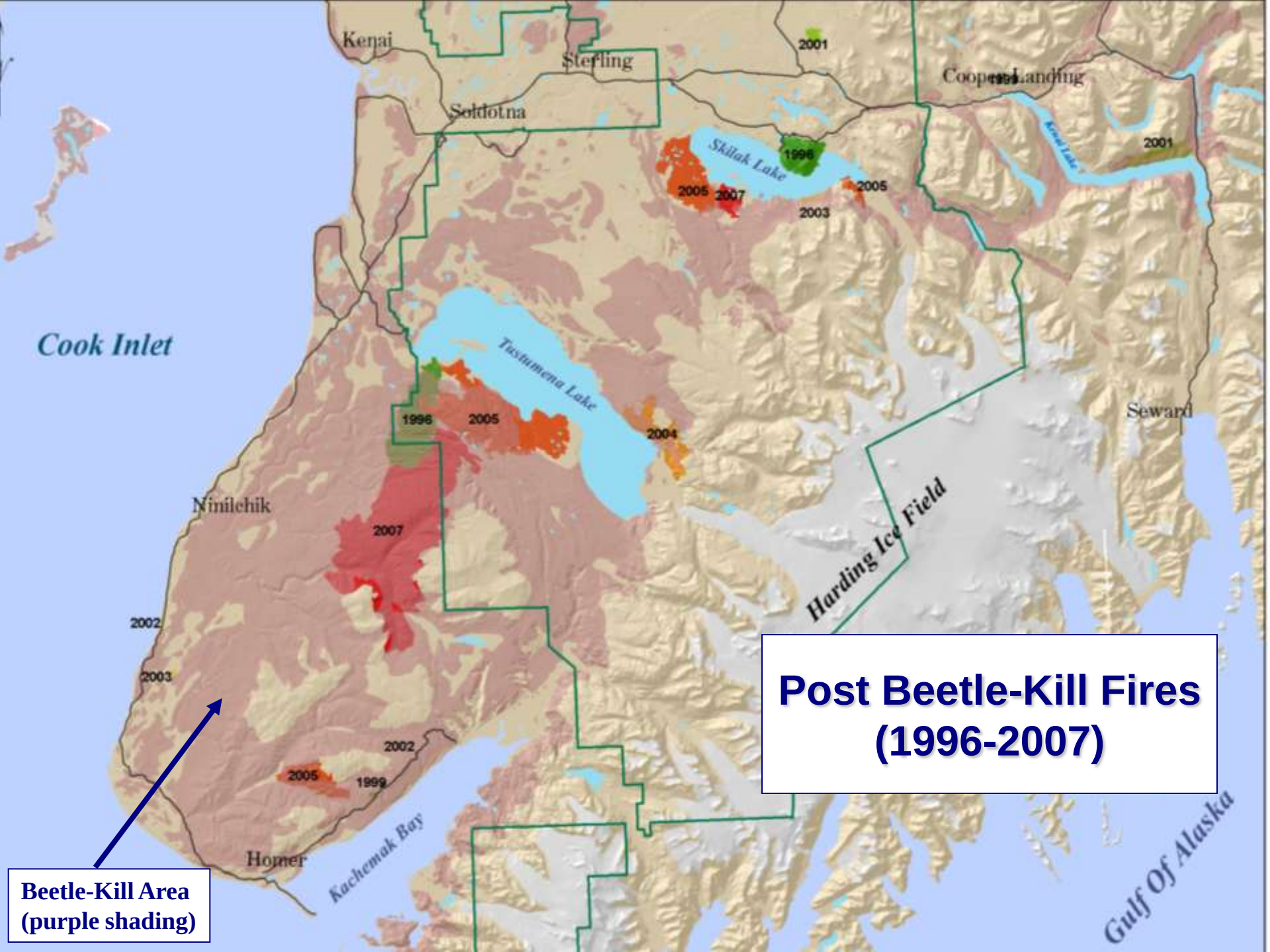
Firestarts 1990-2005

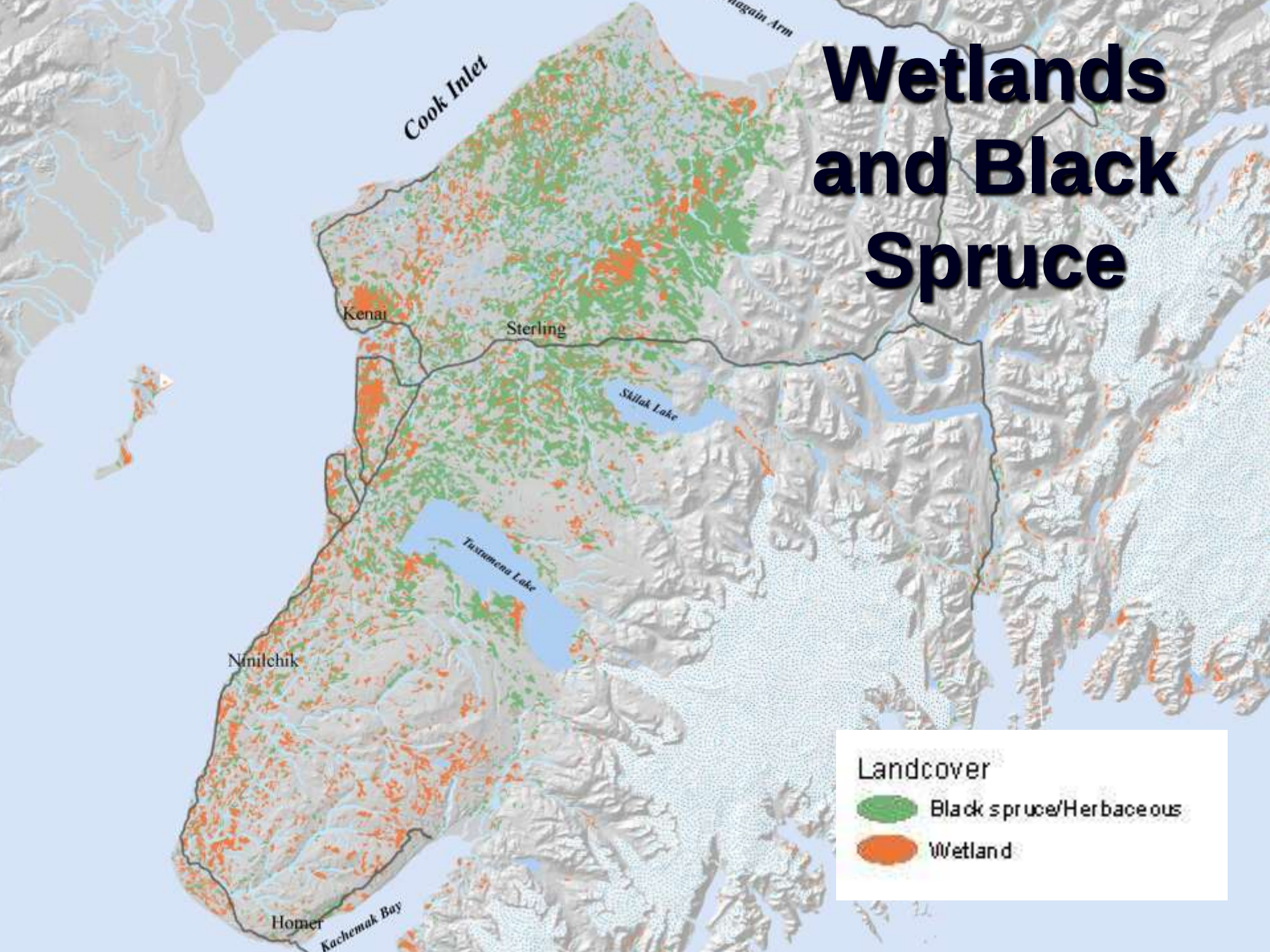


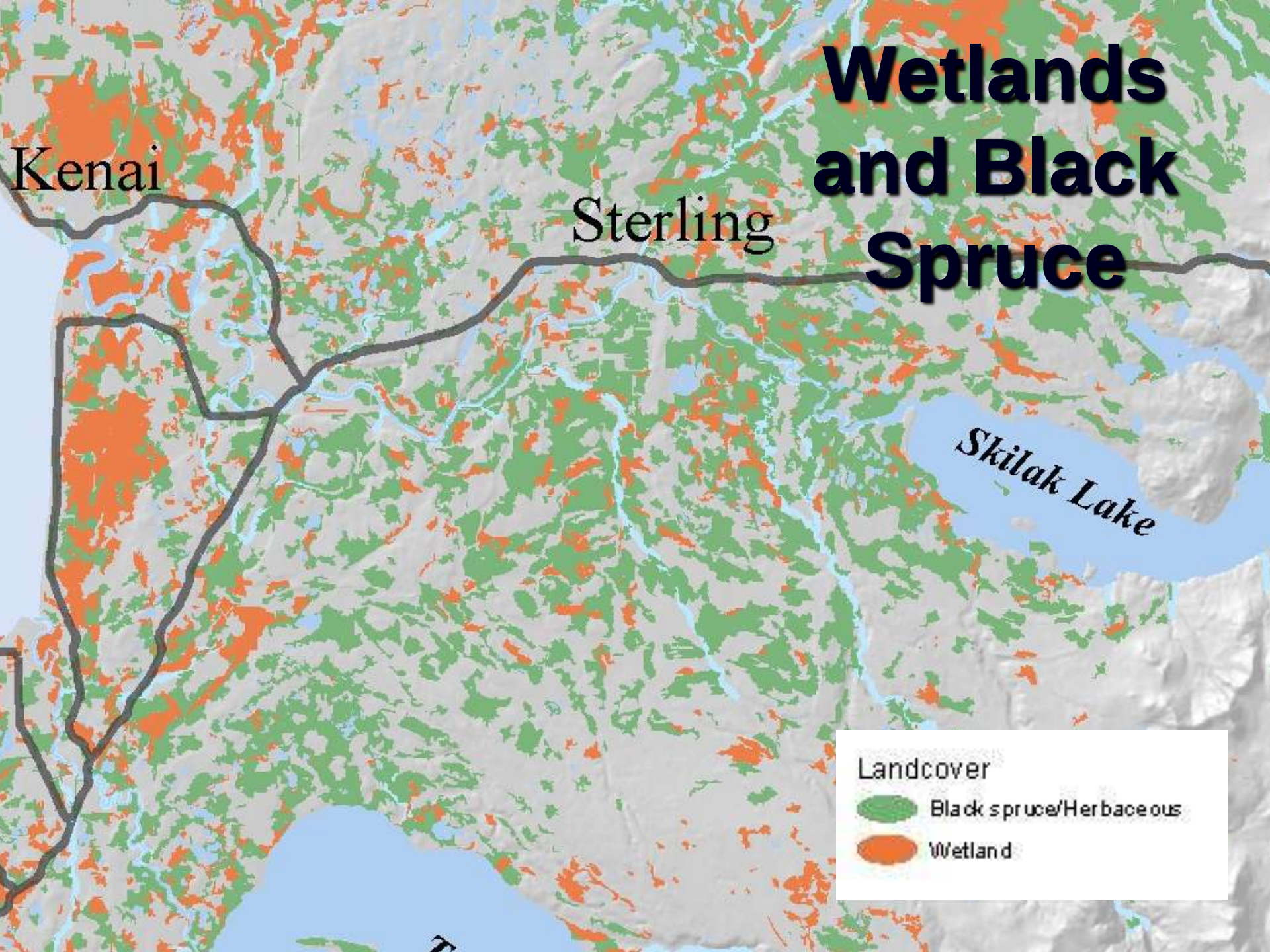
Kenai Fire History

1871-2003




Kenai
Sterling
Soldotna
Cooper Landing
Skilak Lake
Kenai Lake
Cook Inlet
Tustumena Lake
Seward
Harding Ice Field
Ninilchik
Homer
Kachemak Bay
Gulf Of Alaska
2001
1996
2005
2007
2003
2004
1999
2002
Post Beetle-Kill Fires
(1996-2007)
Beetle-Kill Area
(purple shading)


Wetlands and Black Spruce
Cook Inlet
Kenai
Sterling
Skilak Lake
Tustumena Lake
Nanilchik
Homer
Kachemak Bay
Landcover
Black spruce/Herbaceous
Wetland


Wetlands and Black Spruce
Kenai
Sterling
Skilak Lake
Landcover
Black spruce/Herbaceous
Wetland

Bottom Line:
Invasion of shrubs and black spruce into wetlands is converting firebreaks into fuel bridges.

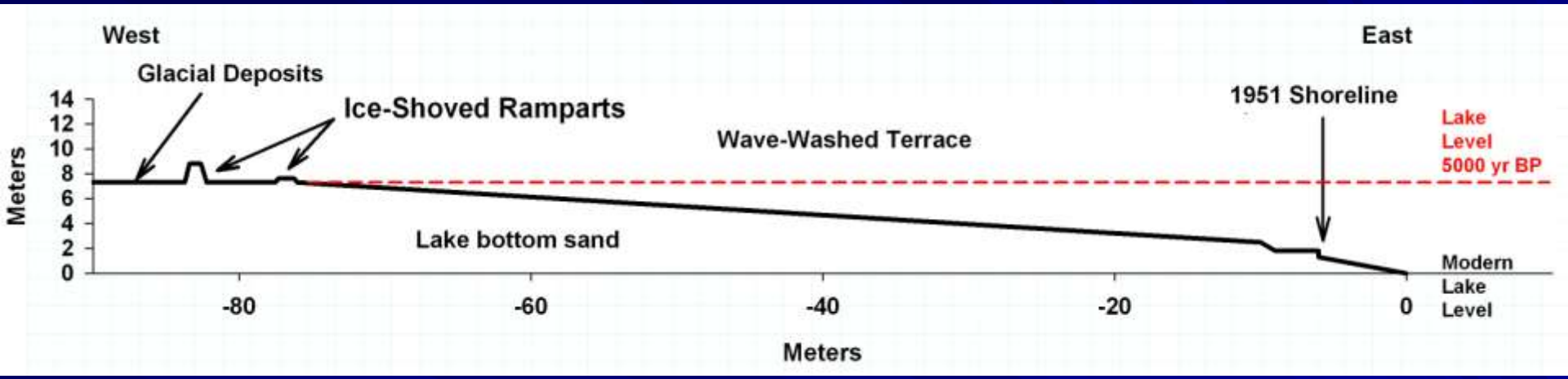
Extreme Climate Periods on the Kenai

Very Wet and stormy – shown by high-water "ice-shoved ramparts." Lake levels were as much as 30-35 feet above modern lake levels (last 5000 years).

Very Dry – Lake levels down by 45 feet (8-10,000 years ago)

Ice-Shoved Ramparts

Cow Lake Profile

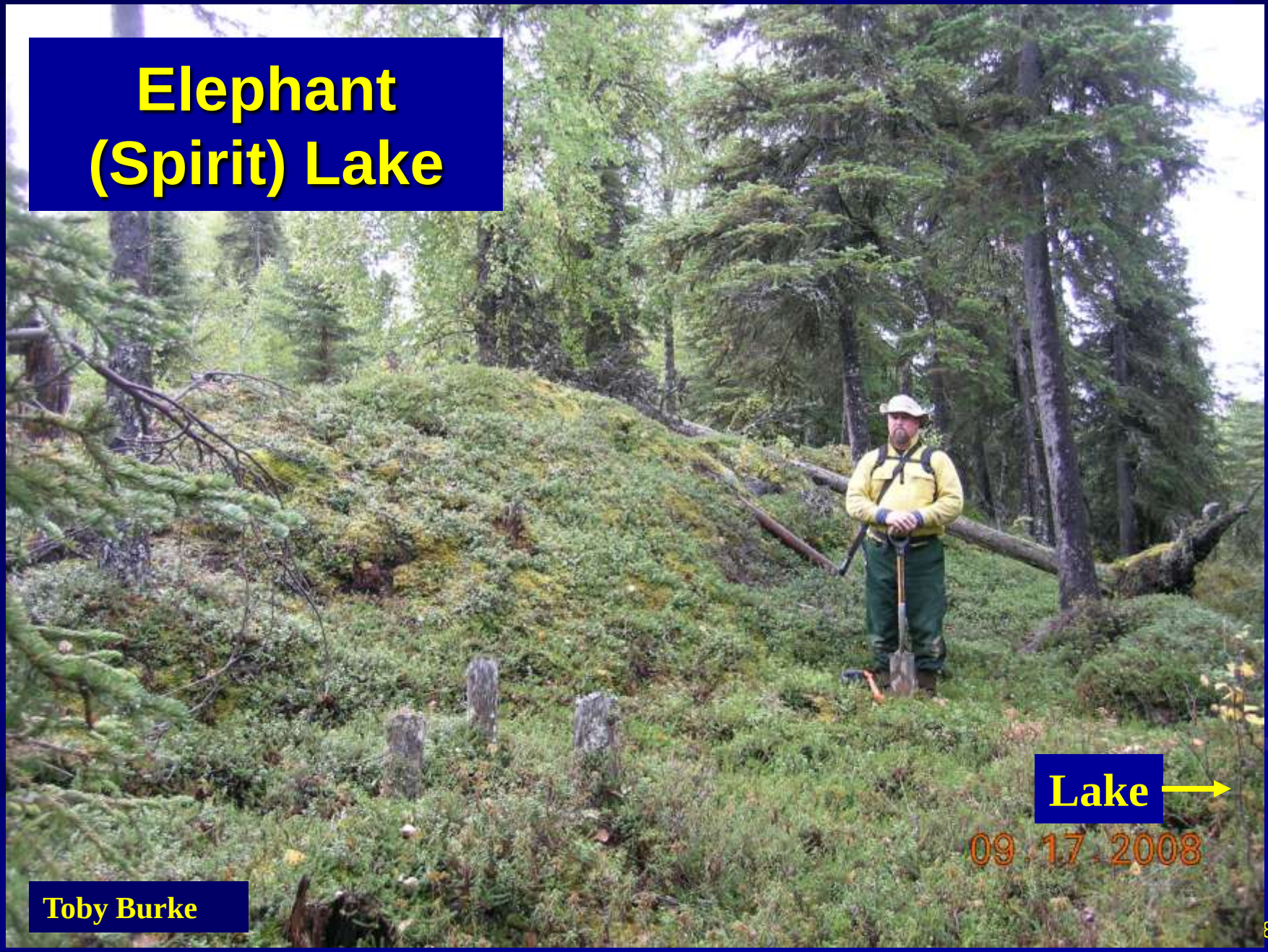


The lake level was 7 meters (23 feet) higher 5000 years ago.

Drawn to scale: no vertical exaggeration

Seam of organic material for radiocarbon dating

Elephant (Spirit) Lake



Elephant (Spirit) Lake

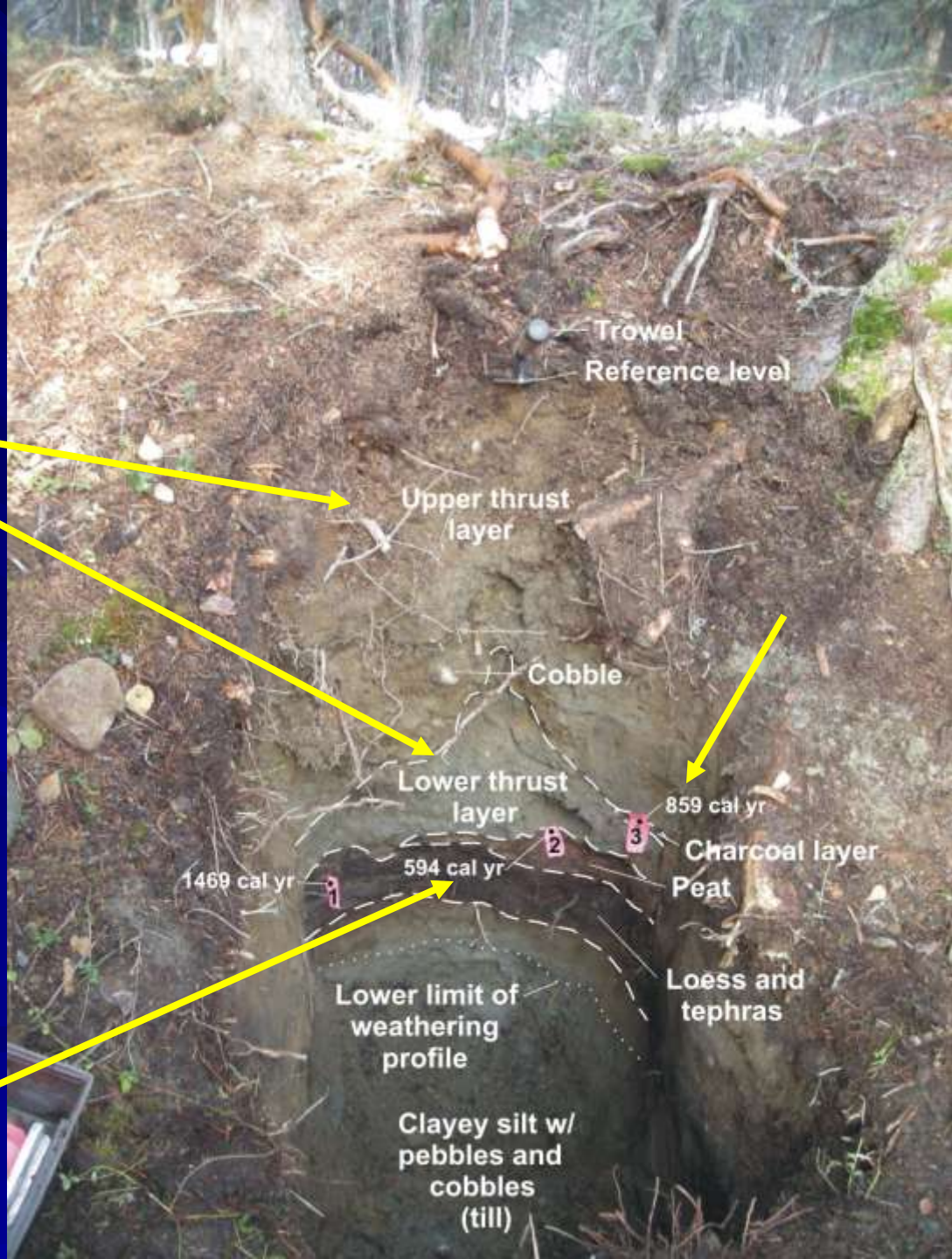
Sunken Island Lake

Dick Reger

Sunken Island Lake Excavation

Sunken Island Lake Soil Profile

Two thrust events



Younger material thrust under older Material (3rd thrust)


Donkey Lake
Lake
06 03 2009

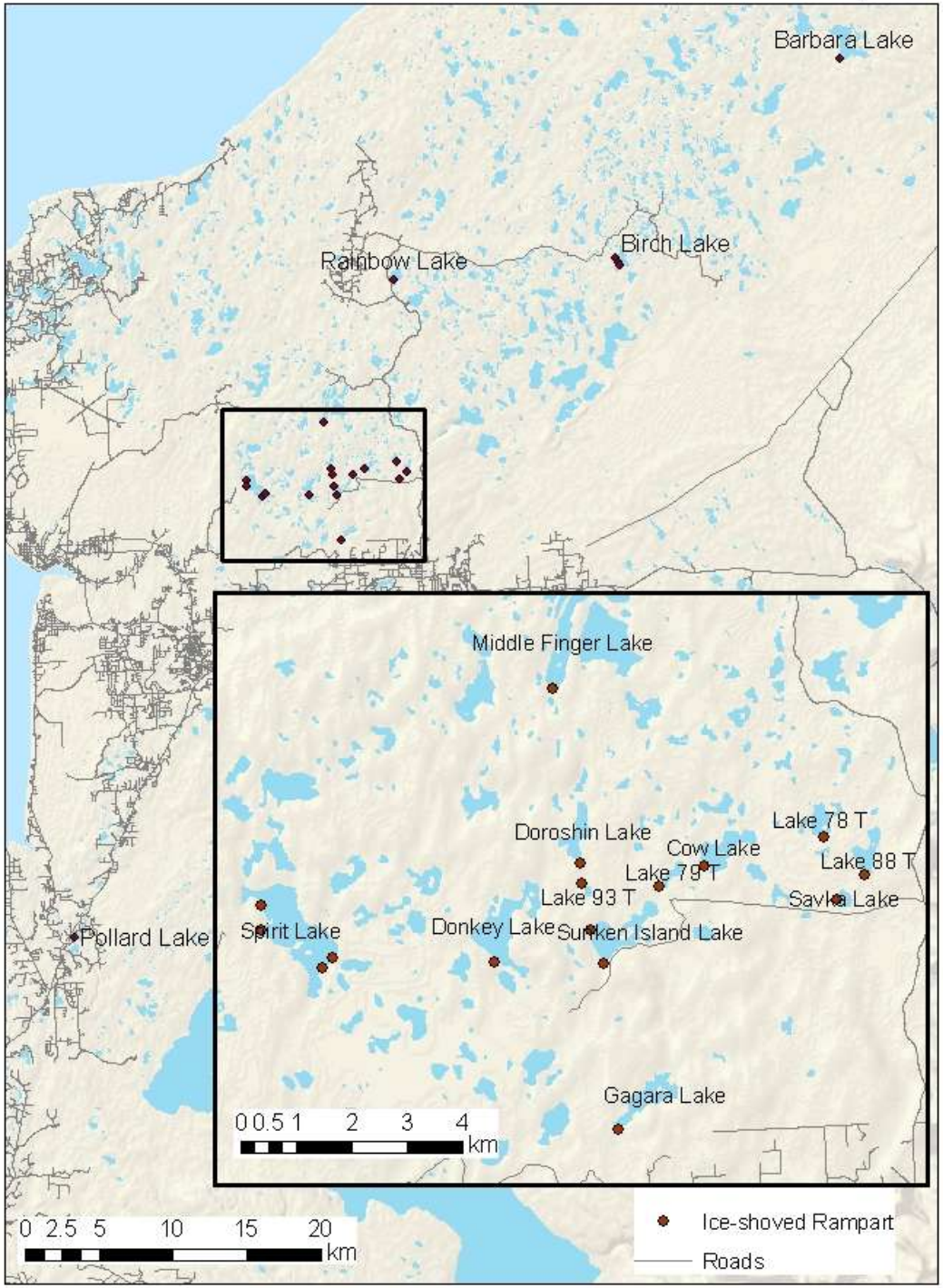

Middle Finger Lake
Lake
07 08 2008

We have so far located 16 lakes on the Kenai with ice-shoved ramparts.

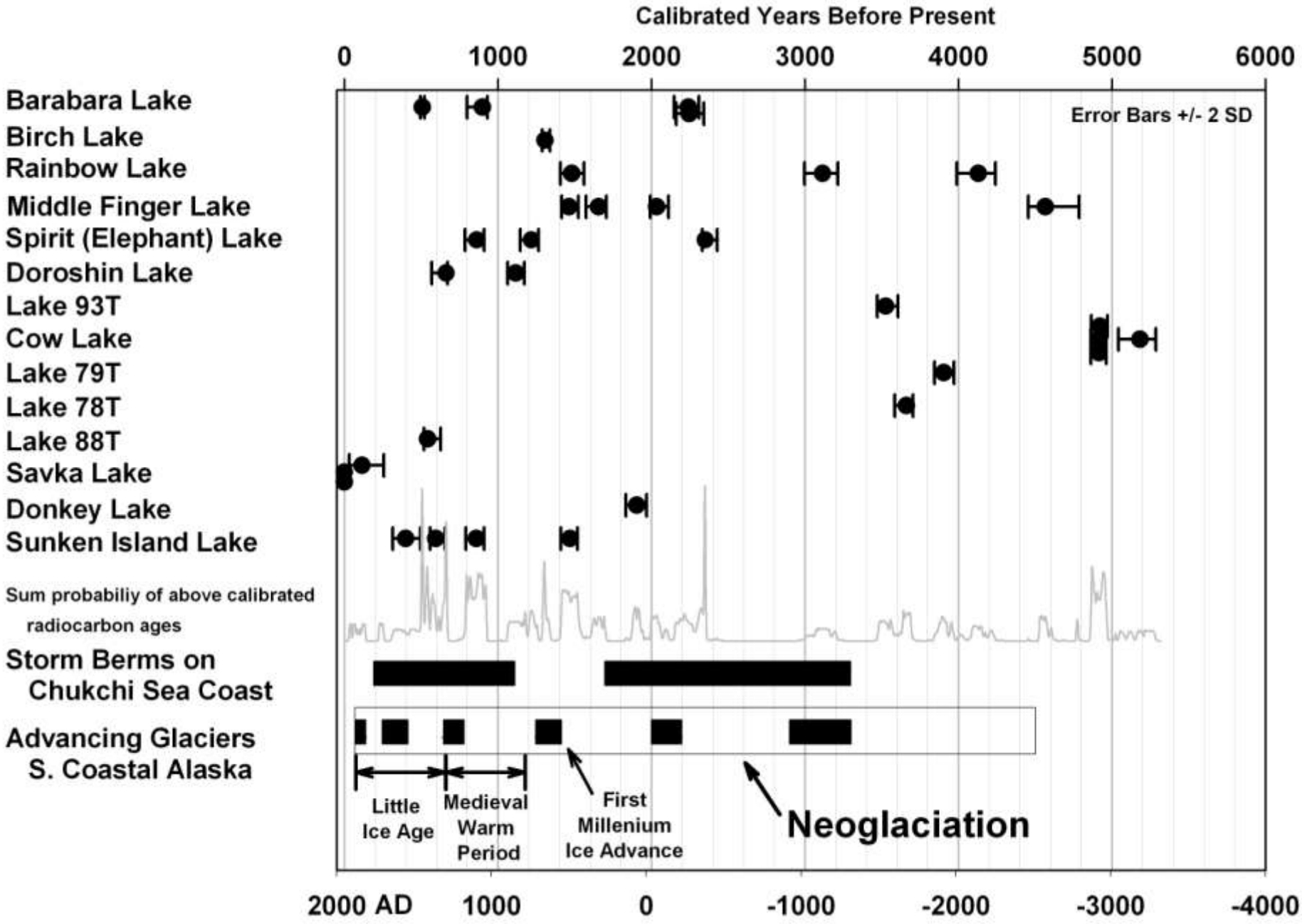
Also, ramparts have been reported in Lake Clark National Park at Lachbuna, Telaquana and Lower Twin Lakes.

Moosehead Lake northwest of Tok has well-developed recent ramparts.

Please let us know if you know of other lakes with ramparts!



Ice-Shoved Rampart Radiocarbon Dates

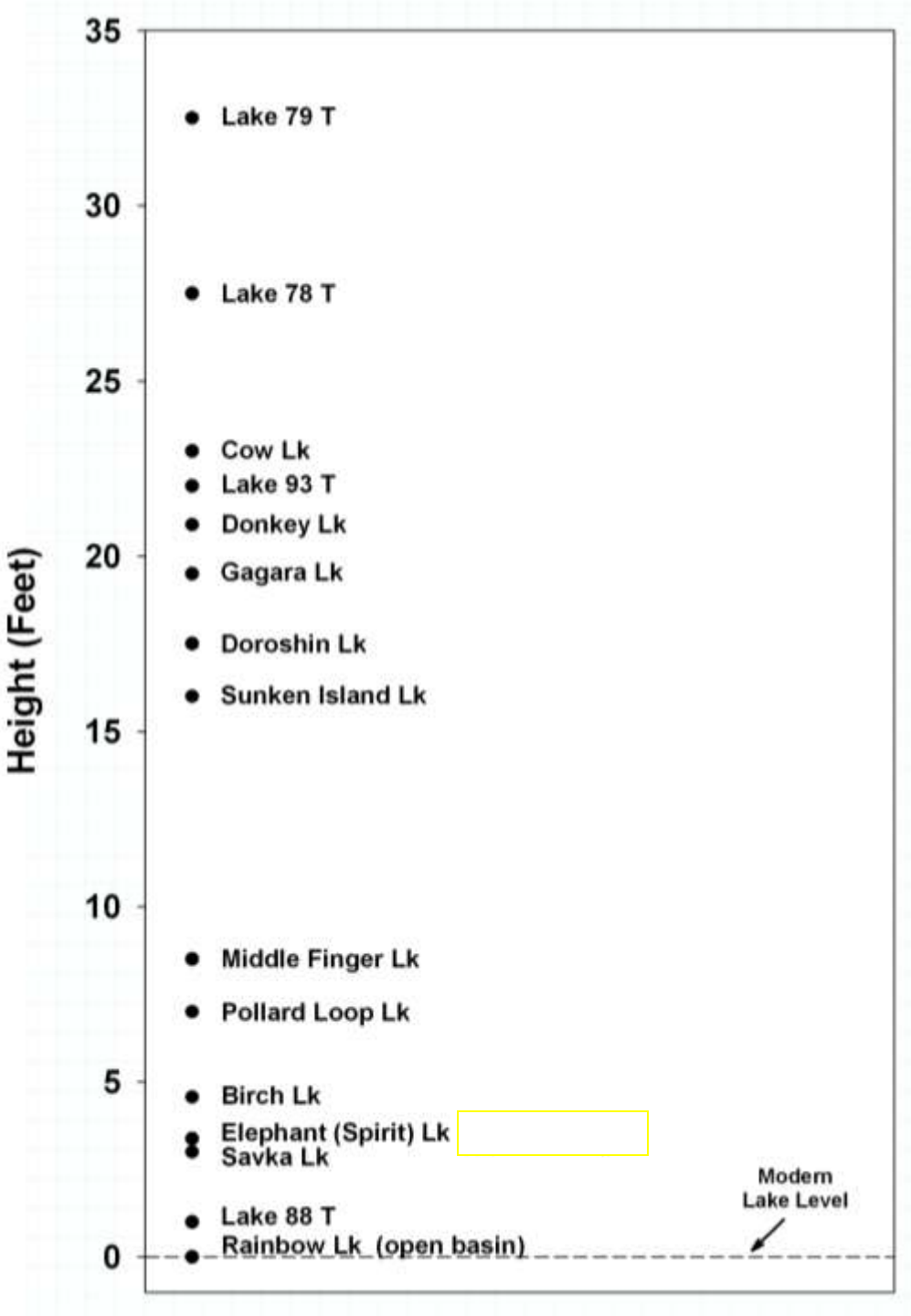


Puzzle: The western Kenai Lowland has been free of glacial ice for the last 19,000 years.

Why are the Ice-Shoved Ramparts only visible in the last 5000 years?

Ice-Shoved Ramparts Heights above Modern Lake Levels

These high lake levels represent extremely wet periods in the past!



An Extreme Dry Period (8000-10,000 years ago)

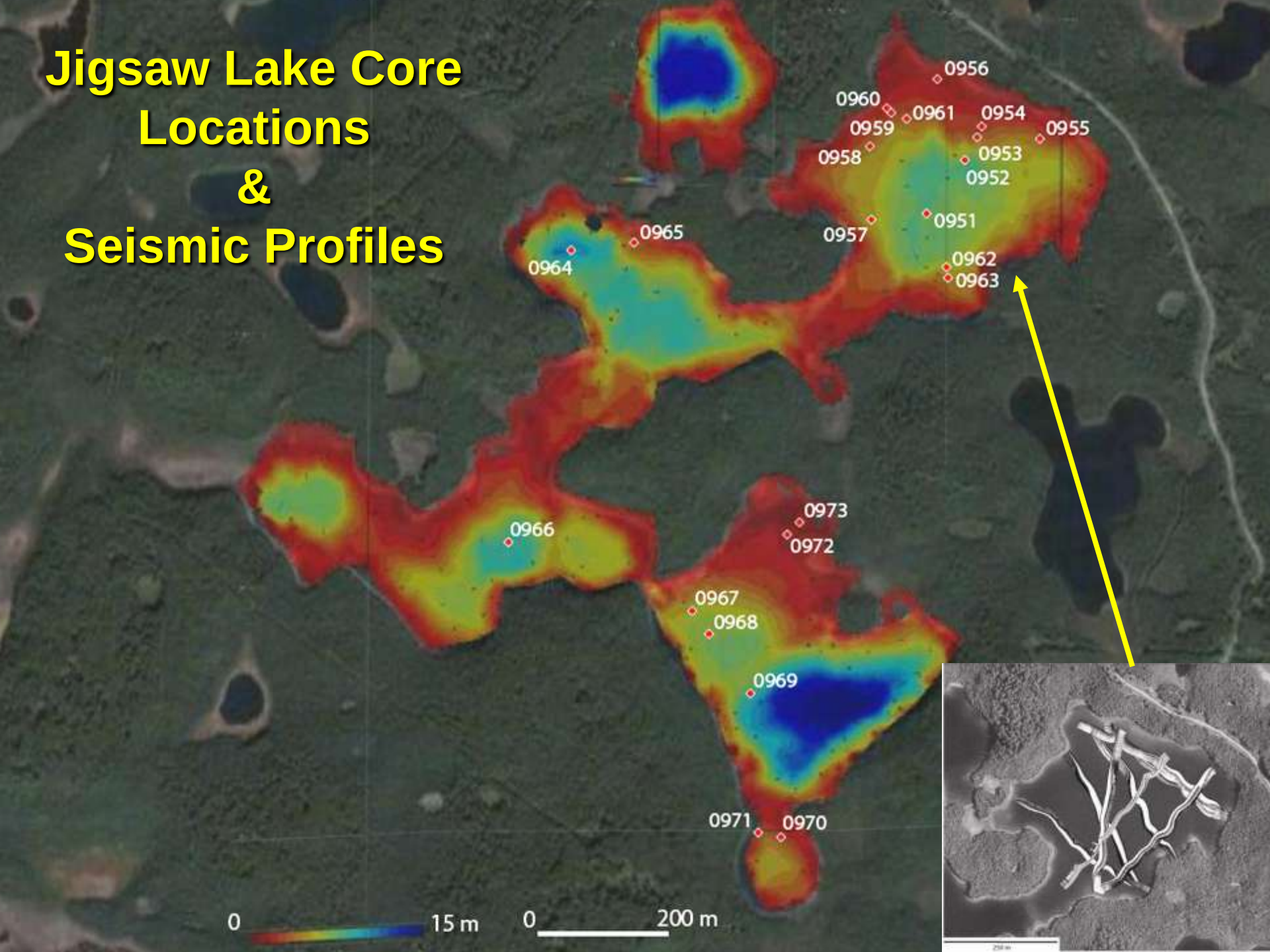
One possible scenario for a future Kenai Peninsula, as seen in lake sediment cores at Jigsaw Lake.

Jigsaw Lake Sediment Coring 2009

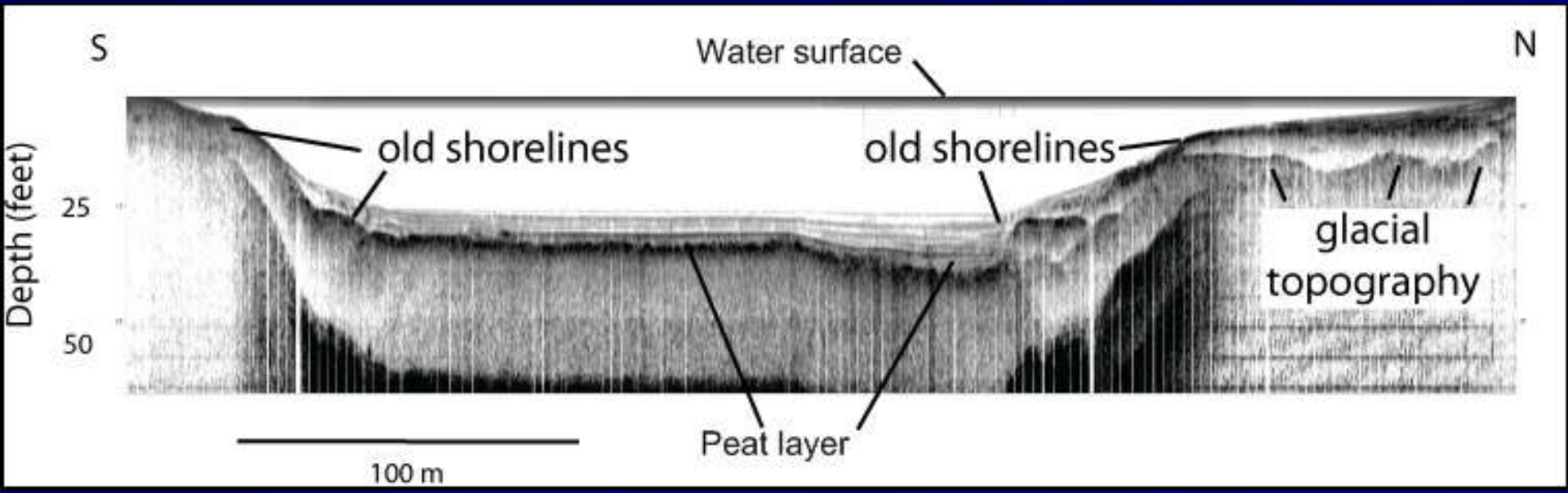
Prof. Tom Lowell

Undergrads Terry Workman and Alena Giesche

Jigsaw Lake Core Locations & Seismic Profiles

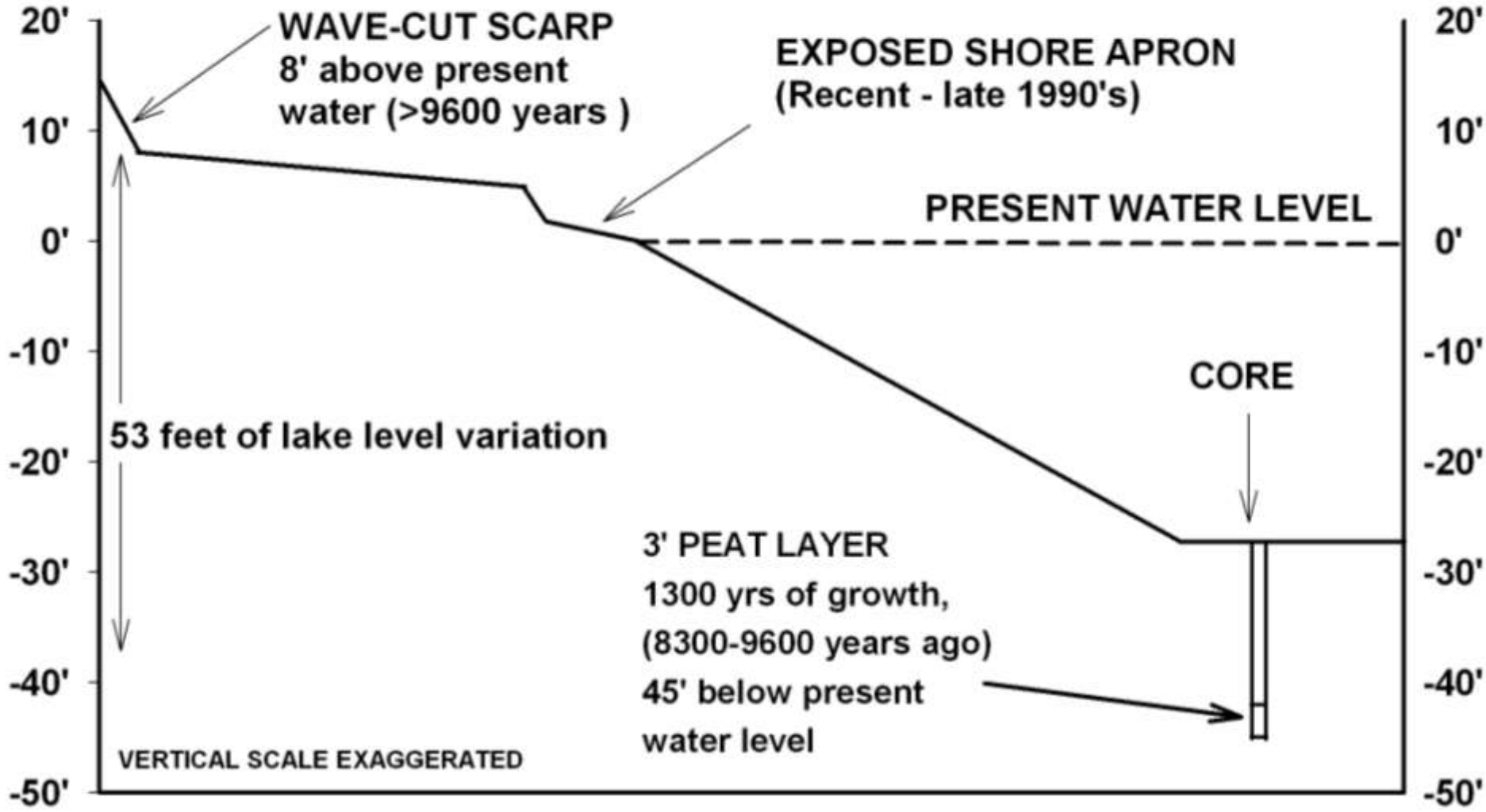


Jigsaw Lake Seismic Profile

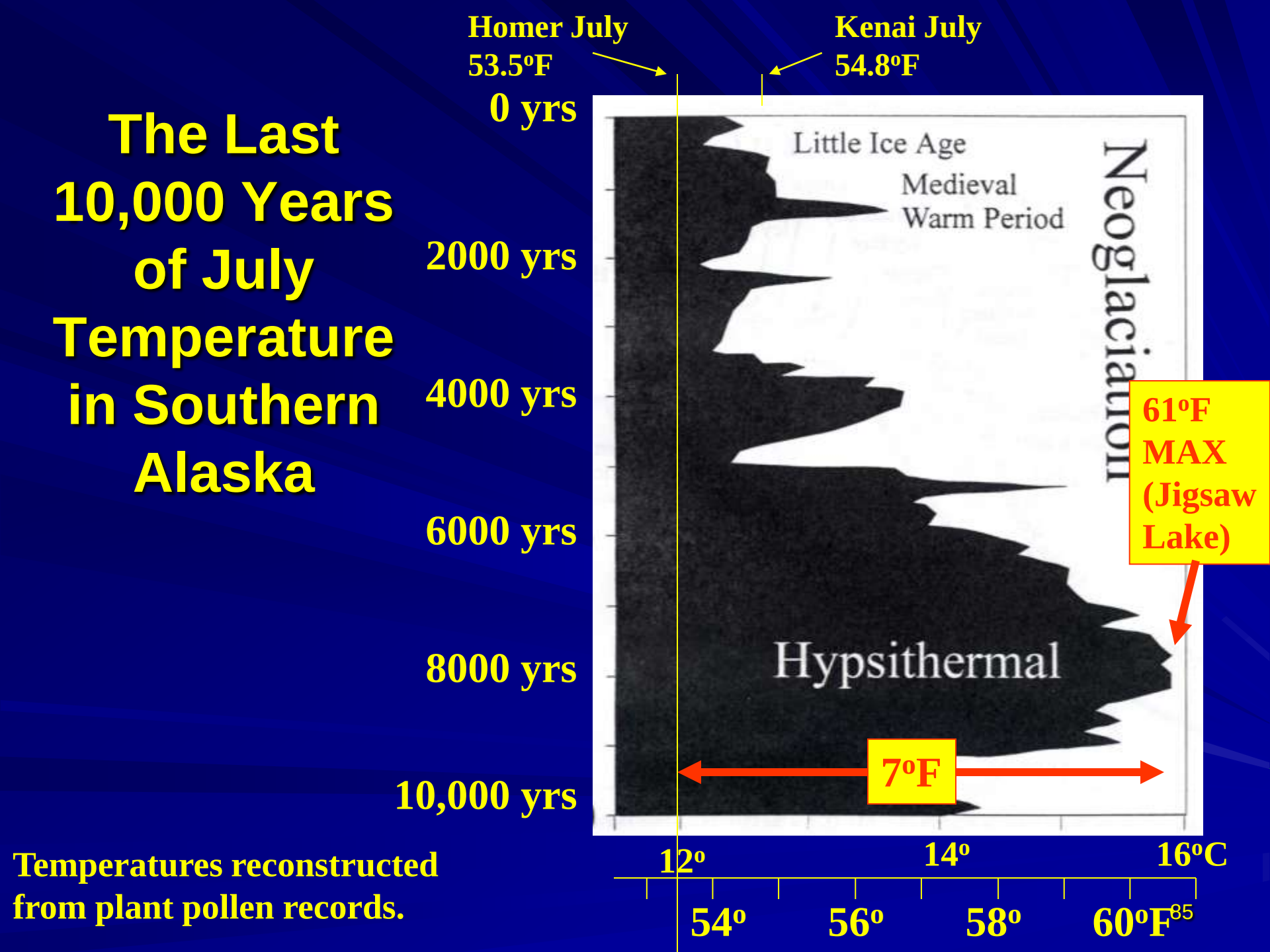


The buried peat layer is as much as 45 feet below the modern lake level, indicating that the lake level was drawn down 45 feet, app. 9500 years ago.

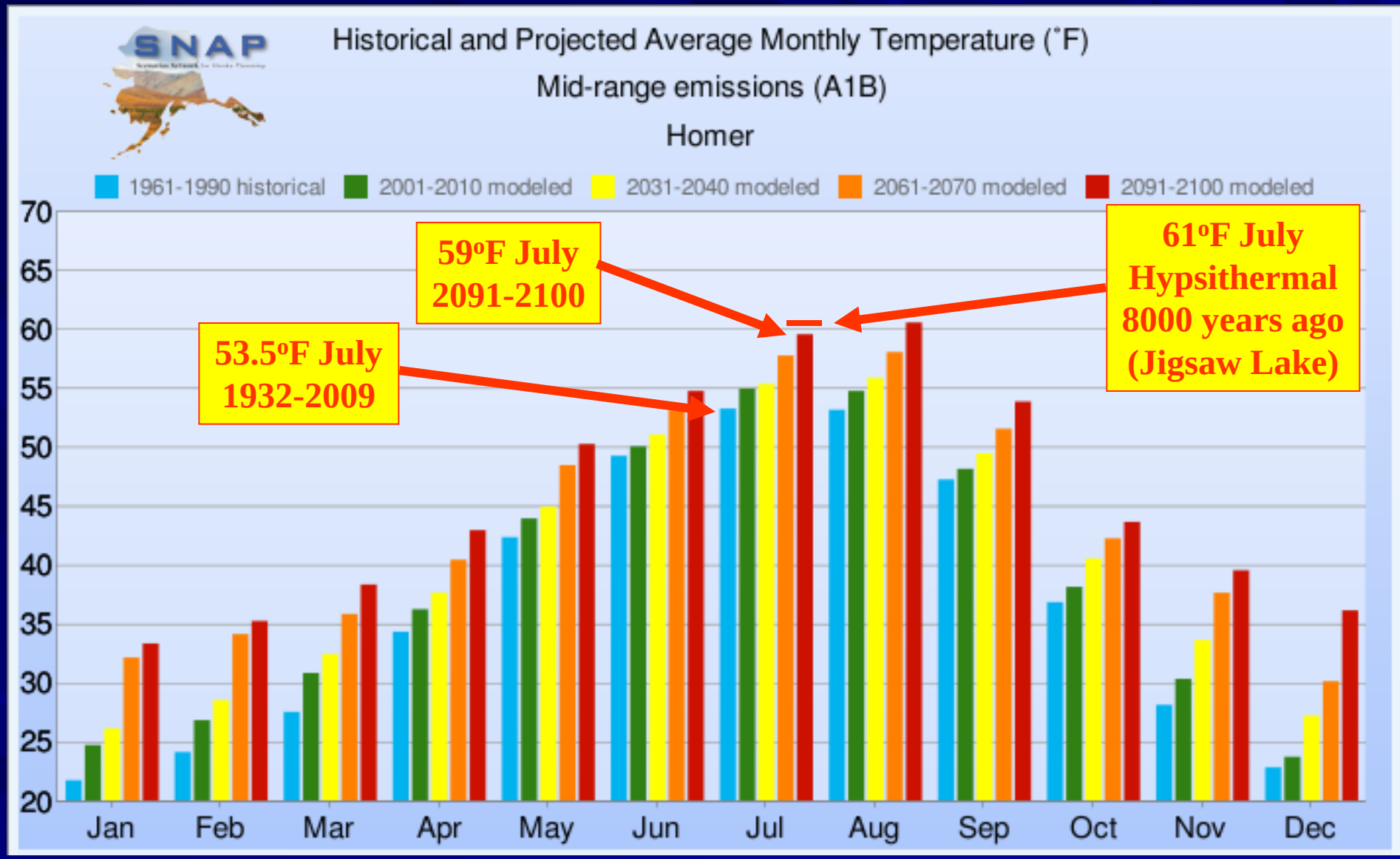
JIGSAW LAKE PROFILE



The Last 10,000 Years of July Temperature in Southern Alaska

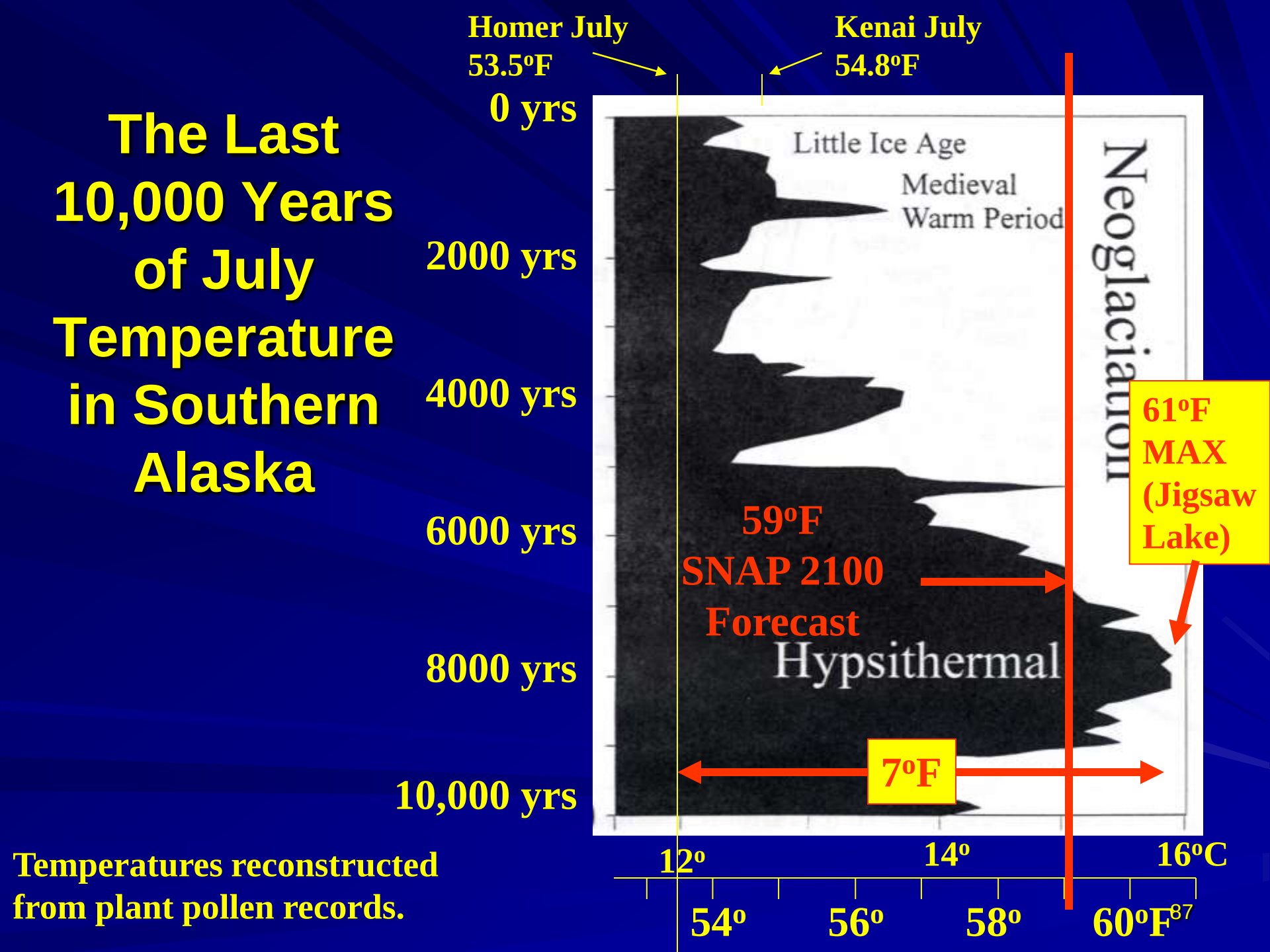


Temperatures reconstructed from plant pollen records.

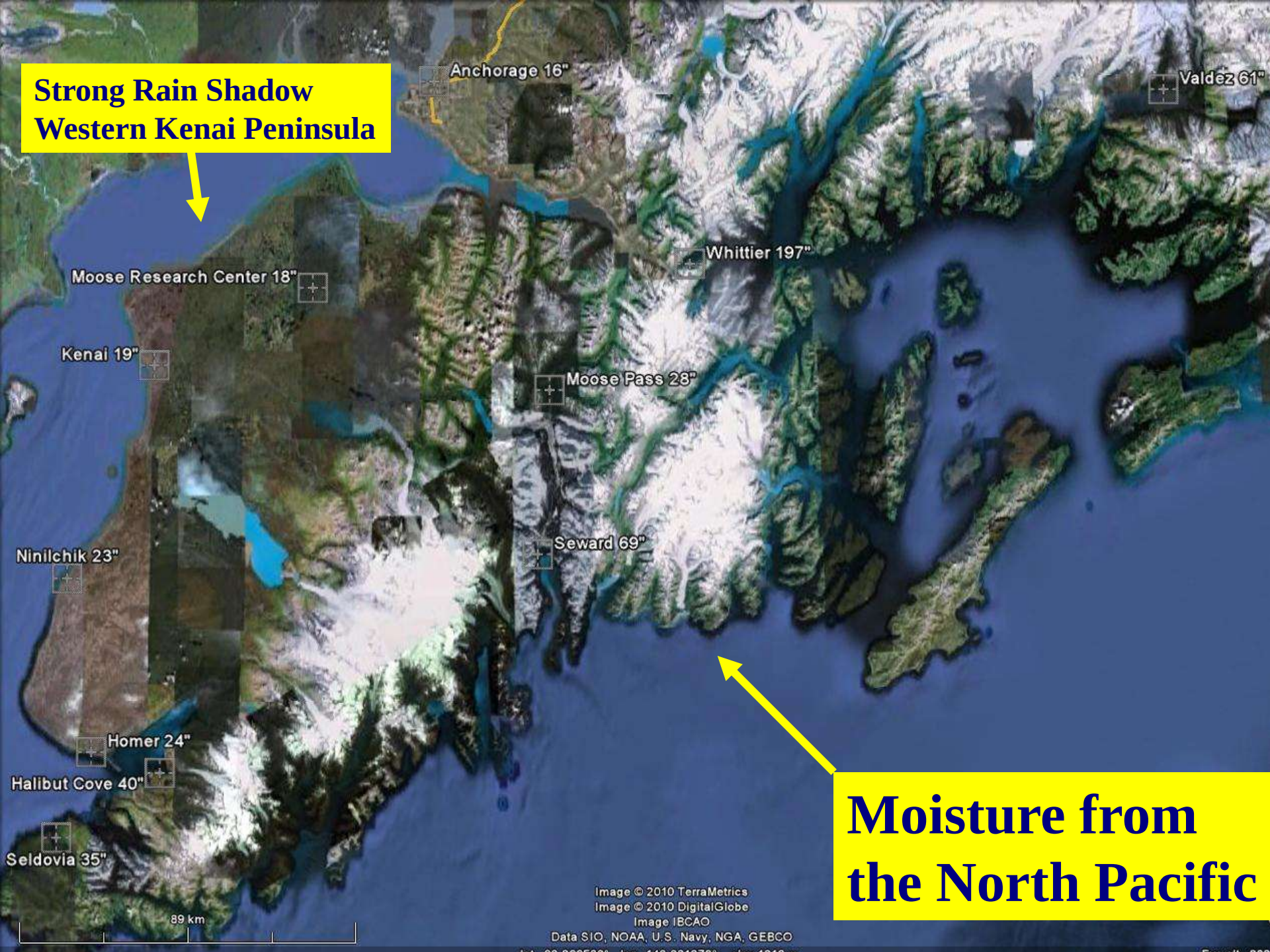


5-Model Average (UAF SNAP forecast)

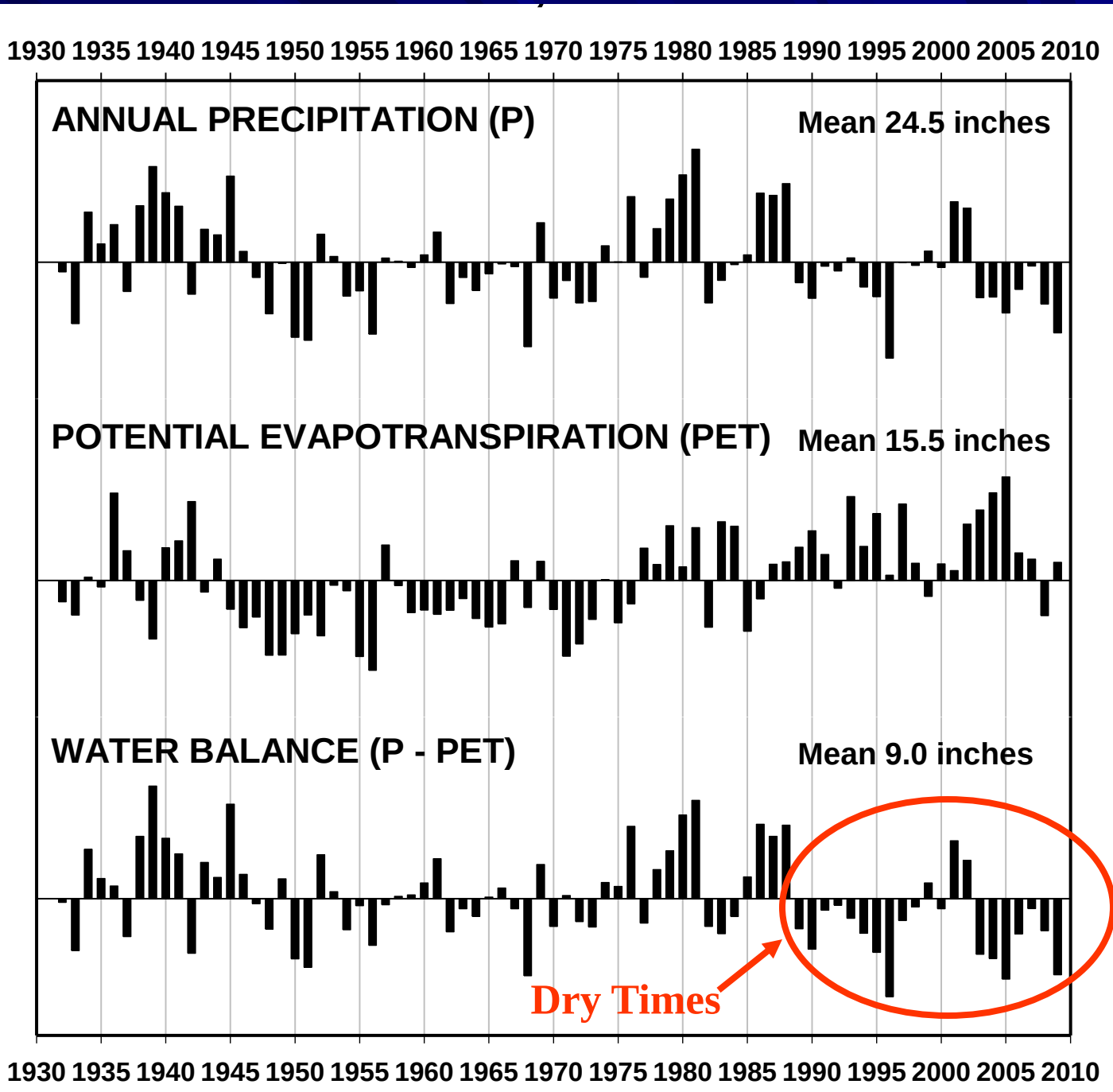
The Last 10,000 Years of July Temperature in Southern Alaska



Temperatures reconstructed from plant pollen records.

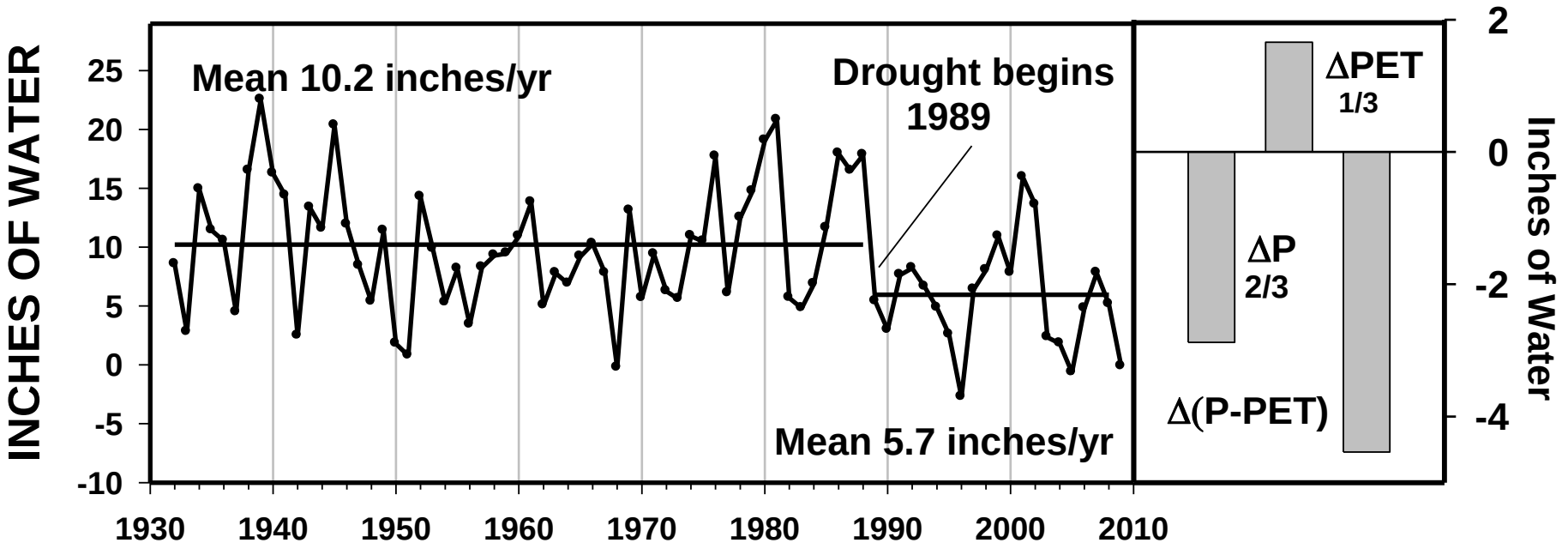

Strong Rain Shadow
Western Kenai Peninsula
Anchorage 16"
Valdez 61"
Whittier 197"
Moose Research Center 18"
Kenai 19"
Moose Pass 28"
Seward 69"
Ninilchik 23"
Homer 24"
Halibut Cove 40"
Seldovia 35"
Moisture from
the North Pacific
Image © 2010 TerraMetrics
Image © 2010 DigitalGlobe
Image IBCAO
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
89 km

The Homer Water Situation



Homer Water Balance (P – PET)

Precipitation (P) - Potential Evapotranspiration (PET)



$\frac{5.7}{10.2}$ = 56%, or a 44% decline in available water

Decreasing precipitation (ΔP) contributes 2/3 of the decline in available water since 1989. Warmer summers (ΔPET) contribute 1/3 of the decline.

(Recall Kenai showed a 59% after 1968.)

Uplift & Sea Level Rise

Tectonic Change – due to plate motions, e.g., 1964 Great Alaska Earthquake

Isostatic Rebound – uplift due to removing the weight of glaciers & icecaps on the crust of the Earth

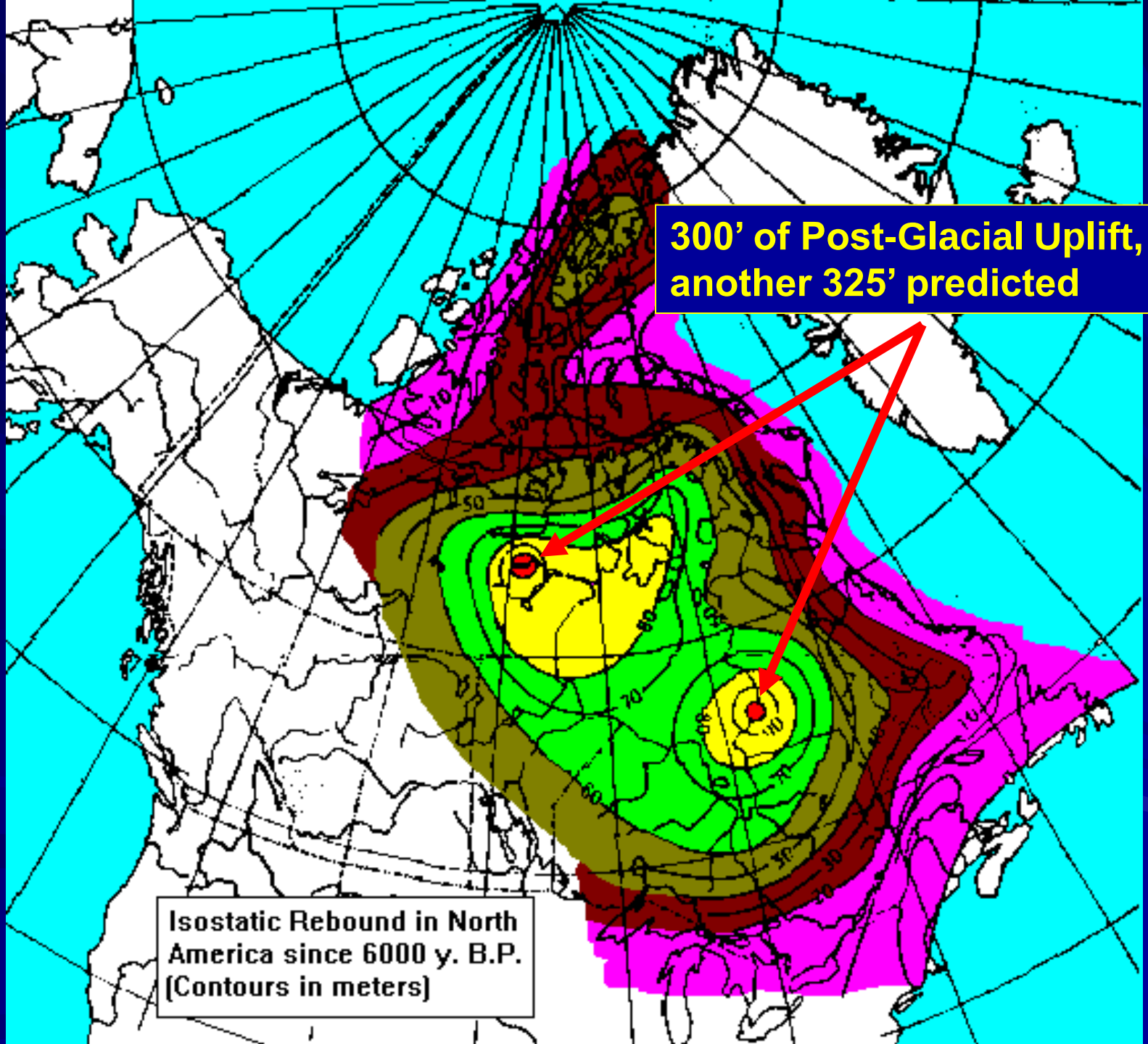
Rising Sea-level – due to adding more water to the oceans (melting glaciers and icecaps)

Classic Emergent Coasts: Pacific Tectonic Uplift

Rocky cliffs, small beaches

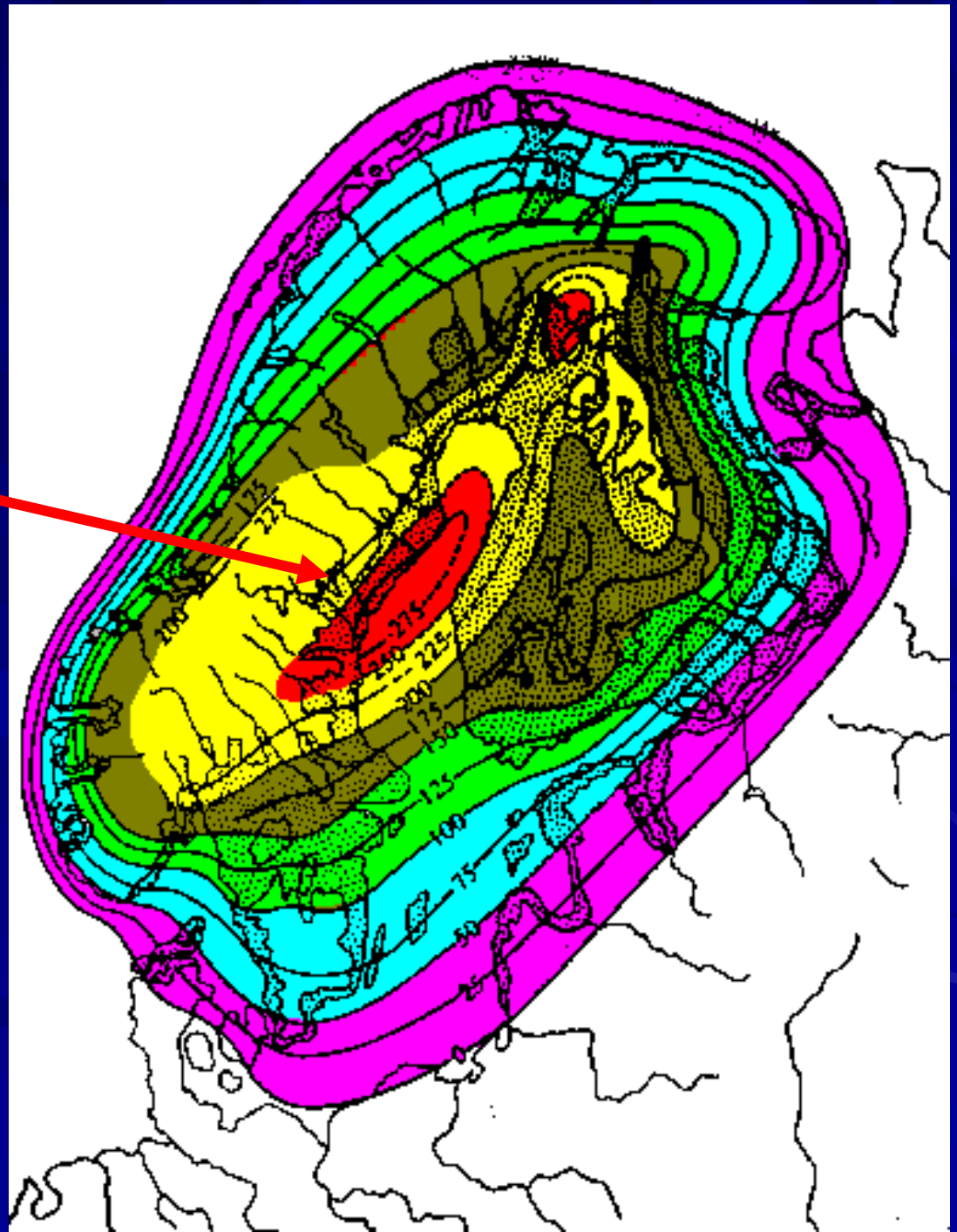
Classic Submergent Coasts: Atlantic Tectonic Subsidence

Coast is clogged with sediments


300’ of Post-Glacial Uplift, another 325’ predicted
Isostatic Rebound in North America since 6000 y. B.P. (Contours in meters)

Fennoscandian Peninsula

900’ of Post-Glacial Uplift In Norway and Sweden



Land Level Change from Tide Gauges

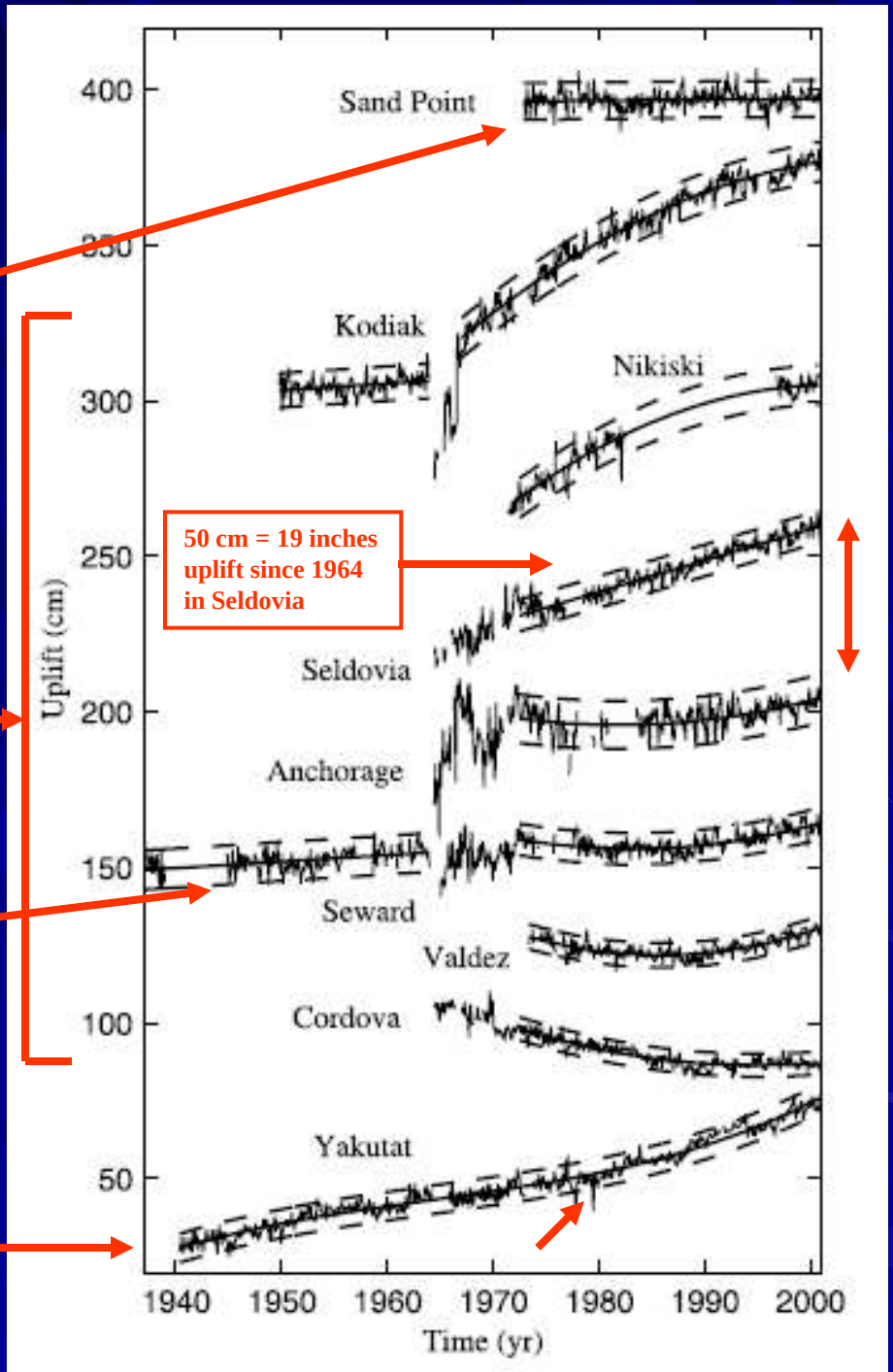
Sand Point shows neither post-1964 EQ adjustment nor glacial isostatic rebound.

These stations show predominantly post-1964 EQ adjustment.

Seward pre-1964 probably shows slight isostatic rebound.

Yakutat shows extreme glacial isostatic rebound, modified slightly by tectonic activity (1979 St. Elias EQ).

Larsen et al. 2003



We are rising 10x faster than sea level

The land level graphs are relative to sea level.

Sea level is rising about 1 mm/year in this area.

Seldovia is rising at 9.6 mm/yr above sea level as of 2000, and shows no sign of slowing down.

Seward is likewise rising at 10.4 mm/yr as of 2000, and also shows no sign of slowing down.

Larsen et al. 2003

Conclusions

The Kenai Peninsula has experienced extreme climate variability since the peak of the Last Glacial Period 23,000 years ago.

During the warm period 8-10,000 years ago, lake levels were down as much as 45 feet. Summer temperatures were 7°F warmer.

During the cooler period of the last 5000 years, lake levels have been up as much as 30-35 feet, accompanied by very strong NE winds.

The coolest period since the last Ice Age was the Little Ice Age (1300-1850 AD).

The landscape has been drying since the 1850s, simultaneous with the glaciers melting back.

The landscape drying has accelerated since the late 1970s.

The coastline in Kachemak Bay is rising 10x faster than sea level is rising at the present time.